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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

1952 DENVER MEETING

AT

DENVER, COLORADO

June 30, July 1, 2, and 3, 1952

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OF THE

AMERICAN PHYSICAL SOCIETY

DENVER MEETING, JUNE 30, JULY 1–3, 1952

THE **314th Meeting of the American Physical Society,** being the sole 1952 Summer Meeting, will be held in Denver, Colorado, on Monday, June 30, and Tuesday, Wednesday, and Thursday July 1–3, 1952. A cordial invitation from the University of Denver has enabled us to convene in this exceptional place, beside the Rocky Mountains and at an altitude surpassed only by Mexico City among our meeting places. What follows will show that our Local Committee has spared no effort to provide us with opportunities both for scientific sessions and for recreation.

This Meeting was originally planned by Byron E. Cohn, the Chairman of the Local Committee, and J. Kaplan, our Local Secretary for the Pacific Coast. To them is due the idea of holding two "discussions" on cosmic rays and one "discussion" and one symposium on upper-atmosphere phenomena: to them also, in the main, is due the choice of participants in these discussions and this symposium. Discussions have been rare in the history of our Society, but the New York meeting of September, 1946, affords a precedent. The administration of each discussion is delegated to the Discussion Leader; all members of the Society are, of course, more than welcome to attend each and all of them.

Hotels. The Cosmopolitan, Shirley-Savoy, Brown Palace, and Olin hotels were listed on the summons card: to these the Local Committee has added the Argonaut. It is to be hoped that our members have heeded the injunction to make their reservations early. Denver is a tourist center, and our meeting occurs at one of the peaks of the tourist season. If anyone should find that he cannot get a room after this Bulletin appears, the Local Committee can do no more than say "You were warned."

The **registration desk** will be on the balcony of the Cosmopolitan Hotel. All members and guests are urged to register, and frequently to consult the adjacent bulletin board for notice of messages. Payment of a registration fee of one dollar will be requested.

Invited papers on the general programme will be given by R. M. Bozorth, W. M. Elsasser, Harvey Fletcher, A. C. Graves, D. B. Hall, H. C. Hoyt, V. H. Regener, S. E. Reynolds, Louis Rosen, R. J. Seeger, D. A. Watkins, and a group of three speakers (G. R. Chambers, J. Feinstein, and H. Staras) from the new laboratories of the National Bureau of Standards at Boulder. The list consists largely but not exclusively of physicists from Colorado and the contiguous states, as is fitting; the variety of topics is intentionally broad.

One hundred and four contributed papers are distributed among nine sessions. The opulence of the programme has prevented the Secretary from reserving Monday morning for a single session at which addresses of welcome and responses might have been presented: this will be compensated at the banquet.

The **locations of the sessions** are given in condensed form in the Epitome and in the captions further along in the Bulletin. The room used in the Cosmopolitan Hotel is the Silver Glade Room. The room used in the Shirley-Savoy Hotel is the Lincoln Room except for Session Q on Wednesday afternoon, when we occupy the Empire Room. The room used at the University of Denver is Room 146 in the Business Administration Building at 1445 Cleveland Place. These three meeting places are only a few blocks apart. Information about public transportation will be given at the registration desk. Taxicab rates per person are not high when three or more people are using the same cab.

The **banquet of the Society** will be held on Tuesday evening at seven in the Student Union Building on the campus of the University of Denver: this is at East Evans and South Vine streets (take an eastbound bus on 15th Street at the corner of Broadway, and allow 30 minutes). The price of the dinner is $3.75. Please use the form on the inside back cover page so that the Local Committee may have an idea how many to prepare for. Tickets will

be sold at the registration desk. The Society reserves the right to sell unpaid-for and uncalled-for reserved tickets to the first comers after 3:00 P.M. on Tuesday.

A **reception** is graciously tendered to the members of the Society and their wives by Mr. and Mrs. John Evans. Mr. Evans is a distinguished citizen of Denver and a patron of science. The day is Monday; the hours are 4:30 to 6:00 P.M.; the place is the residence of Mr. and Mrs. Evans at 2001 East Alameda Avenue. Better take a taxi: the cost is $1.60 for one passenger but rises only by units of ten cents as extra passengers are added.

An excursion to the **Inter-University High-Altitude Laboratories at Echo Lake and Mount Evans** can be made on the fourth of July, provided that enough of our members manifest an interest in advance to justify the chartering of special transportation: the cost (not including meals) will be $9.20. Write early to Professor Byron E. Cohn of the University of Denver, Denver, Colorado.

An excursion to the **Harvard-Colorado High-Altitude Observatory at Climax** can be made on either the fourth or the fifth of July, provided that at least 25 of our members notify Professor Cohn in advance: in this case a bus will be chartered, and the cost per person will be $5. Public transportation is available only to those who are willing to stay overnight at Climax or Leadville.

Neighboring institutions of special interest to physicists comprise: the University of Colorado and the National Bureau of Standards Cryogenics Laboratories at Boulder (30 miles from Denver); the Colorado School of Mines at Golden (15 miles away); Colorado College and the Cheyenne Mountain installation of the National Bureau of Standards at Colorado Springs (70 miles away). No excursions to these places are planned at the moment, but the registration desk will be a source of information about these and other institutions in the neighborhood.

There is an **opera** in Colorado, at Central City (40 miles from Denver). On the evening of July 2 it will present *La Bohème*. Tickets cost $5.50 and transportation costs $2.55. Reservations will be made by Professor Cohn for anyone who notifies him in advance and sends him a check for $5.50; it is doubtful whether seats will still be available after our meeting commences. Buses leave at 4:45 P.M. from Trailways Bus Terminal at 17th and Glenarm streets. There is also a considerable number of **mountains** in Colorado, some visible from Denver: those who wish special information concerning mountain trips may get it at the registration desk.

Members of Sigma Pi Sigma are invited to participate in a luncheon to be given by the University of Denver Chapter on Tuesday at 12:30 in the YWCA dining room at 1545 Tremont Place, two blocks north and west of the Shirley-Savoy Hotel. The price will be $1.25, and those who will attend are asked to present themselves before noon on **Monday** at the Sigma Pi Sigma "courtesy desk" which will be near to our registration desk.

The **Council of the American Physical Society** will meet on Monday at 10:45 A.M. in Room 109 of the Business Administration Building of the University of Denver at 1445 Cleveland Place.

Post-deadline ten-minute papers, pertaining to very recent achievements of very special importance, will be considered for admission to a special supplementary programme if the abstracts are received at the office of the Society not later than Monday, June 23. The abstracts will not be printed. The titles of such papers as may be accepted will be announced on a blackboard near the registration desk, and the papers will be given under the usual ten-minute rule at the end of Session L.

Prospective meetings of the Society are scheduled to be held in St. Louis on November 28–29, 1952; at Pasadena near the end of 1952; and at Cambridge, Massachusetts (the 1953 Annual Meeting) on January 22–24, 1953.

Titles and abstracts of the papers contributed to the Denver meeting are printed hereinafter, and in exactly this form they will reappear in an early issue of *The Physical Review*. Errata will be printed on an adjacent page of *The Physical Review* if received not later than Friday, July 18th, by Miss Ruth Bryans, American Institute of Physics, 57 East 55th Street, New York 22, New York. Write out your corrections in the form "instead of . . . "read . . ."; do *not* send in your abstract marked with corrections. Do not add anything.

Speakers must retrieve their lantern slides before leaving the room in which they spoke. The Local Committee must not be burdened with the task of saving and returning them.

KARL K. DARROW, *Secretary*
American Physical Society
Columbia University
New York 27, New York

EPITOME OF THE 1952 DENVER MEETING

(Personal names are those of invited speakers.)

Monday Morning

A. Atmospheric physics; Elsasser. Shirley-Savoy.
B. Reactions of transmutation. Cosmopolitan.
C. General physics; fluid dynamics. University of Denver.

Monday Afternoon

D. Neutrons and general nuclear physics; positronium. Cosmopolitan.
E. Electronic and solid-state physics. University of Denver.
F. Regener, Reynolds, Chambers, Feinstein, Staras. Shirley-Savoy.

Monday Evening

G. Graves. Cosmopolitan.

Tuesday Morning

H. Apparatus of nuclear physics; mesons. Cosmopolitan.
I. Radioactive substances. University of Denver.
J. Bozorth, Watkins. Shirley-Savoy.

Tuesday Afternoon

K. Cosmic rays. Cosmopolitan.
L. Optical physics. University of Denver.
M. Fletcher, Seeger. Shirley-Savoy.

Tuesday Evening

Banquet of the American Physical Society. University of Denver.

Wednesday Morning

P. Discussion on the components of the cosmic radiation. Cosmopolitan.

Wednesday Afternoon

Q. Rosen, Hall, Hoyt. Shirley-Savoy (Empire Room).
R. Temperature, composition and motions of the upper atmosphere: Van Allen, Manning, McNish, Newell, Jones. Cosmopolitan.

Thursday Morning

S. Discussion on composition, winds, pressures, and temperatures of the upper atmosphere. Shirley-Savoy.

Thursday Afternoon

T. Discussion on the new unstable particles in cosmic radiation. Shirley-Savoy.

PROGRAMME

MONDAY MORNING AT 10:15

Shirley-Savoy

(J. KAPLAN presiding)

Atmospheric Physics

A1. Recombination Processes in Oxygen.* JOSEPH KAPLAN AND MARX BROOK, *University of California, Los Angeles.*—The suggestion by M. Dufay that Krassovsky's observation of a night airglow emission at 9976A can be interpreted as the O−2 band of the forbidden atmospheric system of O_2, continues to confirm the fact first discovered by Kaplan in O_2 afterglows, that the $v'=0$ level of the $^1\Sigma$ state is probably exclusively observed, since bands originating on $v'>0$ are very weak or absent. The suggestion by D. R. Bates that selectivity could be produced by a secondary mechanism $O_2'\Sigma(v'>0)+O_2{}^3\Sigma(v''=0)=O_2{}^3\Sigma(v''>0)+O_2'\Sigma(v'=0)$ is discussed in the light of current ideas regarding the Herzberg and Vegard-Kaplan bands in the night airglow. The relationship between these observations in O_2 and the afterglows associated with very weak electrical discharges in N_2 and in N_2-O_2 mixtures is discussed, since the $v'=0$ selectivity was first discovered in the latter. This discussion indicates that the primary three-body recombination process is directly responsible for the $v'=0$ selectivity and that no secondary process is required. Experiments designed to clarify the mechanism responsible for the selectivity in O_2 will be described.

* This work has been sponsored by the Geophysical Research Division of the U. S. Air Force.

A2. Observation of Non-Rayleigh Scattering in the Very Near Infrared Spectrum of the Day Sky. ROMUALD ANTHONY, *Inyokern.*—Spectra of the day sky were obtained at several different azimuth angles away from the sun for approximately constant solar elevation. The region from 0.55μ to 2.2μ was recorded using a PbS cell receiver. By comparing the sky spectrum with the direct solar spectrum recorded a few minutes earlier, it was possible to observe the change in the spectral distribution that appears for different regions of the sky. The change is indicated by a graph which is a plot of the $\log(I_s/I_d)_\lambda$ *vs* $\log\lambda$ where I_s and I_d are the recorded sky and direct solar intensities, respectively. Experimental data of the solar spectrum and the sky spectrum published by Arthur Adel[1] were plotted in the same manner. Both curves are similar showing a pronounced discontinuity at approximately $\lambda=0.85\mu$ with a sudden increase in slope toward 1.2μ. Computed values of the "reduced scattering functions" $\sigma'(\varphi)$ *vs* α published by H. Holl[2] show a curve of precisely the same form.

[1] A. Adel, Phys. Rev. **76**, 446 (1949).
[2] H. Holl, Optik **4**, 173 (1948-49).

A3. Radiative Transfer and Equilibrium Associated with Far Infrared Bands in the Atmosphere.* J. I. KING, *University of Utah.*—Earlier theories of radiative heat transfer and equilibrium did not take into account the proportionality of line width with pressure. Within the region, however, where collision broadening prevails (up to heights of about 40 km) the pressure and hence line width decreases by a factor of about 200. Strong and Plass[1] recently considered this effect for an isothermal stratosphere, neglecting mutual overlapping of neighboring lines. We have been able to set up in analytical terms the equations of radiative transfer and equilibrium for pressure-broadened lines, both without and with overlapping. The latter case is a generalization of the earlier absorption formula of Elsasser for equal, equidistant lines. Numerical solutions of these equations are now being worked out. In addition we have proved a theorem stating that all such radiative equilibrium configurations have temperatures monotonically decreasing with height. Hence a near-isothermal stratosphere seems to require sources of heat other than far infrared transfer, e.g., the ultraviolet absorption of ozone.

* Supported by the Geophysics Division, Air Force Cambridge Research Center.
[1] J. Strong and G. N. Plass, Astrophys. J. **112**, 365 (1950).

A4. Spectral Solar Energy in the Near Infrared.* DAVID M. GATES, ROBERT F. CALFEE, AND BYRON E. COHN, *University of Denver.*—The spectral solar energy distribution in the near infrared between 1.0 and 6.0 microns was determined using a Perkin-Elmer Model 12C infrared spectrometer with NaCl optics. The solar radiation and the radiation from a Globar operated at 1441°K were alternately focused on the spectrometer entrance slit. At a given wavelength position and a fixed slit width the instrumental response to the Globar was determined and the solar energy attenuated by means of an iris diaphram aperture situated in the solar beam to give the same response. From the diameter of the aperture, the geometry of the system, and the known Globar emission the apparent solar emission in ergs/cm²/sec/unit wavelength interval was calculated. The values determined represent only apparent energies as seen through the earth's atmosphere. From 1.5 to 1.7 microns where atmospheric absorption is small the energies approach those characteristic of a blackbody at 7000°K. Determinations were made in Denver, Colorado, during periods of reduced atmospheric moisture during December, 1951 and January, 1952.

* The research reported in these papers has been sponsored by the Geophysics Research Division of the Air Force Cambridge Research Center.

A5. Atmospheric Water Vapor Determination by Means of Infrared Solar Spectroscopy.* ROBERT F. CALFEE, DAVID M. GATES, AND BYRON E. COHN, *University of Denver.*—The Perkin-Elmer Model 12C infrared spectrometer was used to obtain data concerning the atmospheric absorption of solar radiation in the region between 0.9 and 2.0 microns. Determinations were made with the atmospheric water vapor content ranging from one millimeter to one centimeter of precipitable water in the zenith direction. The earlier work of F. E. Fowle on transparency of aqueous vapor was essentially substantiated with some corrections. The spectrographic findings were compared with the meteorological soundings taken daily at Lowry Air Force Base at Denver, Colorado. Calibration curves for each telluric water band ρ, ϕ, and ψ were established. In order that reliable results should be obtained certain precautions with respect to slit width, recording speed, amplifier gain and other parameters need to be observed.

* The research reported in these papers has been sponsored by the Geophysics Research Division of the Air Force Cambridge Research Center.

A6. Atmospheric Ion Monitor. J. D. GRAVES, W. R. KETLER, AND R. I. CONDIT, *Broadview Research and Development.*—A compact, portable instrument to measure the concentration of ions in the atmosphere has been developed.[1] It consists of an ion chamber of cylindrical symmetry open to the atmos-

phere and provided with a blower for forcing air through the chamber. Electrical charges from the atmospheric ions are collected on the central electrode as the air passes through the chamber. Charges thus collected in this dynamic ion chamber are equivalent to those in a static ion chamber of much larger volume. The flow of air may be increased for greater sensitivity until disturbances within the air stream cause the formation ions. For sensitivity and freedom from fluctuations, a non-turbulent flow is desired. Since the insulator supporting the collecting electrode is exposed to the atmosphere, special precautions were taken in the design with respect to its voltage gradient, composition, temperature, and the circulation of air in its vicinity. The electric current resulting from the collected charge is amplified and indicated by conventional electrometer circuits. The completed device operates as a detector of high sensitivity (large collecting volume) free from absorbing walls or windows (open to the atmosphere).

[1] Initiated and supported in part by the Wesix Electric Heater Company of San Francisco, California.

A7. Local Atmospheric Ion Concentrations as a Basis for Personnel and Plant Protection. R. I. CONDIT, *Broadview Research and Development.*—The existing measurements of the ion concentrations in the atmosphere[1] have emphasized the natural conditions which exist free from the disturbances of man. In addition to these natural phenomena, however, the local ion concentrations within the confined spaces of buildings may be an effective and convenient indicator of certain industrial hazards. The local ion concentration is generally increased by the action of ionizing agents (flames, electrical discharges, nuclear radiation, ultra-violet light, static electricity); effected one way or the other by reactive gases (electropositive or electronegative); and influenced by certain dispersions of dust. Thus the atmospheric ion monitor may serve to guard against fire, escaping gases, electrical disturbances, radioactive contamination, and a variety of special technical hazards. In principle, the same monitor may even serve simultaneously to guard against several of the more likely dangers in a given plant. For example, a particular installation may be set up to monitor continuously the effectiveness of static electricity suppression around rotating machinery, while operating at the same time as a standby detector for the outbreak of fire and/or the explosion of an atomic bomb.

[1] J. A. Fleming, *Terrestrial Magnetism and Electricity* (Dover Publications, Inc., New York, 1949), Chapter IV.

A8. Wind and Temperature Measurements Above the Lower Isothermal Region of the Atmosphere by Acoustic Propagation Studies (July 1950–May 1951).* WILLIAM B. KENNEDY, *University of Denver* (introduced by Robert S. Bradford).—During the period July, 1950 through May, 1951, three sets of data per month were obtained from field observations sufficient for the determination of high level winds and temperatures. The method of operation and calculation employed was developed by A. P. Crary.[1] These studies show that, in the winter months, the upper winds (20 to 50 km) were of relatively large magnitude (greater than 30 m/sec) from the Northwest, and in the summer months, these winds were of lesser speeds (less than 30 m/sec) and Easterly. An analysis of results obtained show that the annual mean temperatures in the 20 to 45 km region were as shown in Table I.

TABLE I.

Altitude above sea level (km)	Annual mean temperature (C)
20	−61
25	−58
30	−49
35	−34
40	−14
45	−2

* This research is supported by the Geophysical Research Directorate of the Air Force, Cambridge Research Center.
[1] A. P. Crary, J. Meteorol. **7**, 233 (1950).

Invited paper

A9. The Theory of Infrared Radiation in the Atmosphere. W. M. ELSASSER, *University of Utah.* (30 min.)

MONDAY MORNING AT 10:15

Cosmopolitan

(N. E. BRADBURY presiding)

Reactions of Transmutation

B1. Determination of the Cross Section of the Reaction $H^3(d, n)He^4$. J. P. CONNER, T. W. BONNER, AND J. R. SMITH, *Rice Institute.*—The reaction $H^3(d, n)He^4$ has been studied with bombarding deuterons for energies of 10 kev up to 1700 kev. Thin zirconium-tritium targets have been used. The cross section shows a pronounced peak at 109 kev and at this energy the total cross section was measured to be 5.1 ± 0.2 barns. From very low energies up to 800 kev a good fit to the experimental curve was given by the Breit-Wigner formula. Cross sections above this energy were larger than predicted by the one level formula.

B2. Cyclotron Bombardments with 21-Mev He^3. T. W. DONAVEN, D. N. KUNDU, JOHN K. LONG, AND M. L. POOL, *Ohio State University.*—A small amount of He^3 obtained from Oak Ridge was introduced into the cyclotron tank and accelerated to 21 Mev as calculated from the frequency of 13.5 Mc/sec. A recirculation cycle was worked out in course of which the oil diffusion pump was backed by two mercury diffusion pumps in parallel. The gas from the exhaust outlet of the mercury pumps was freed by a liquid hydrogen trap from the air which entered the system through natural leakage. The He^3 gas was then reinjected into the system. Neutrons and gamma-rays from a Be target were used to detect initially the resonance of the He^3 beam. A prominent 20-minute positron activity was produced from Be presumably from the reaction $Be^9(He^3, n)C^{11}$. A strong 1.8-hour positron activity of F^{18} was evident in all targets bombarded. This is attributable to small traces of oxygen on the targets.

B3. Angular Distribution of Protons from the Reaction $He^3(d, p)He^4$.* J. L. YARNELL, R. H. LOVBERG, T. F. STRAT-

TON, AND W. R. STRATTON, *University of Minnesota.*—The differential cross section for the production of protons by the reaction $He^3(d, p)He^4$ has been measured in the energy range 0.25 to 3.5 Mev. Monoergic deuterons from the Minnesota electrostatic generator were used to bombard a thin gaseous target of He^3. The protons emerged from the reaction chamber through a thin window and were detected in a NaI scintillation counter. Observations were made between the angles of 16° and 137° in the C-M system. The total cross section exhibits a broad maximum at 430±30 kev, and decreases slowly with energy above the resonance. The differential cross section above 1.5 Mev shows a minimum which moves to smaller angles as the energy is increased. Preliminary measurements show that the angular distribution at the peak of the resonance is anisotropic. Further data being taken at low energies will be reported.

* Supported by the joint program of the AEC and ONR.

B4. Cross Sections for $Li^6(n, p)He^6$, $Li^7(n, d)He^6$, and $Be^9(n, \alpha)He^6$ for 14-Mev Neutrons.* M. E. BATTAT AND F. L. RIBE, *Los Alamos Scientific Laboratory.*—Formation of He^6 by bombardment of Li^6, Li^7, and Be^9 with 14-Mev neutrons has been observed. The He^6 was identified by its 0.85 second half-life[1] and the decay observed on a ten-channel time-delay analyzer with channel widths of 0.4 and 1.0 second. The He^6 beta-rays were detected by means of a thin-walled aluminum proportional counter filled to 65-cm pressure with a Kr-CO^2 mixture. An over-all counting efficiency was determined by using the $Cu^{63}(n, 2n)Cu^{62}$ reaction, the cross section for which is known to an accuracy of 7 percent.[2] The effect of scattering and absorption of the beta-rays in Li and Be was measured. Targets of Be, normal Li, and enriched Li^6 and Li^7 were used. The cross sections determined for the $Li^6(n, p)$, $Li^7(n, d)$, and $Be^9(n, \alpha)He^6$ reactions were 6.7±0.8, 9.8±1.1, and 10±1 millibarns, respectively. The half-life of He^6 was found to be 0.83±0.3 second.

* Work performed under the auspices of the AEC.
[1] Natl. Bur. Standards Circular 499 (1950).
[2] S. G. Forbes, private communication.

B5. Low-Lying Levels of Al^{25} Observed from the $Mg^{24}(d, n)Al^{25}$ Reaction.* E. GOLDBERG,† *University of Wisconsin.*—A 67-kv Mg^{24} target was bombarded with 4.007-Mev deuterons and the neutrons from the $Mg^{24}(d, n)Al^{25}$ reaction were detected at seven angles with Ilford C2 emulsions. Preliminary readings of 1200 tracks at two angles indicate the presence of at least seven levels of Al^{25} of energies less than 3.4 Mev. Three of these are virtual and confirm previous findings from the $Mg^{24}+p$ elastic scattering[1] and capture[2] data. It is anticipated that additional information will be available from the emulsions exposed at the five other angles.

* Work supported in part by the Wisconsin Alumni Research Foundation and in part by the AEC.
† AEC Predoctoral Fellow.
[1] Mooring, Koester, Goldberg, Saxon and Kaufmann, Phys. Rev. **84**, 703 (1951).
[2] Grotdal, Lönsjö, Tangen, and Bergstrom, Phys. Rev. **77**, 296 (1950).

B6. An Absolute Low Energy Cross Section Experiment.* J. A. PHILLIPS, W. R. ARNOLD, G. A. SAWYER, E. J. STOVALL, JR., AND J. L. TUCK, *Los Alamos Scientific Laboratory.*—A 5-millimeter-diameter pencil of collimated and analyzed deuterons passes through an 8-millimeter-diameter SiO window 7 $\mu g/cm^2$ thick into the target gas at 1-millimeter pressure. The beam current is measured on the high vacuum side of the film uncomplicated by neutral gas and charge exchange effects and with effective guard ring precautions. In the gas a length of the beam is viewed at 90° by two diametral proportional counters. The measured small divergence of the beam together with a measured counter slit system gives a definite target volume and calculable geometry. The gas temperature and pressure are observed continuously, the latter by a sensitive diaphragm micromanometer continuously calibrated against an absolute fluid manometer. The beam energy and its distribution in the target volume are determined separately by allowing the beam to continue into a retarding field and measuring the current as a function of a retarding potential. Cross sections for the reactions DDp, DDn, DT, DHe^3 have been completed.

* Work performed under the auspices of the AEC.

B7. DD Cross Sections 14–110 Kev.* W. R. ARNOLD, J. A. PHILLIPS, G. A. SAWYER, E. J. STOVALL, JR., AND J. L. TUCK, *Los Alamos Scientific Laboratory.*—Measurements have been obtained at 50 points over the above range with 1 percent statistics and 6 percent estimated over-all accuracy above 25 kev. By changing the gas pressure and window thickness in the proportional counters, and using a 6-channel recorder, protons and He^3 nuclei, and, as a check, H^3 were separately counted. The observations were made at 90°, and the integrated cross sections derived from the angular distributions of Bretscher and French.[1] A selection of the results are given in Table I. $\sigma_{DD\ total}$ lies on a Gamow plot of slope 19.34 $\log_{10}$ barns kev/kev$^{\frac{1}{2}}$ close to the theoretical value. The branching ratio $\sigma_{DDn}/\sigma_{DDp}$ approaches a steady value of 0.94 at the lowest energies.

TABLE I.

E_D kev	15	30	45	60	75	90	105
σ_{DDp} millibarns	0.079	1.17	3.6	6.7	10.1	13.4	16.4
σ_{DDn} millibarns	0.074	1.10	3.4	6.5	9.8	13.1	16.1

* Work performed under the auspices of the AEC.
[1] E. Bretscher and A. P. French, Phys. Rev. **75**, 1154 (1949).

B8. TD Cross Sections 15–125 Kev.* E. J. STOVALL, JR., W. R. ARNOLD, J. A. PHILLIPS, G. A. SAWYER, AND J. L. TUCK, *Los Alamos Scientific Laboratory.*—Using 99 percent tritium gas in the target chamber, about 50 measurements at 90° have been obtained over the above energy range with 1 percent statistics and 6 percent estimated over-all accuracy above 25 kev. A selection of the cross sections obtained, assuming an isotropic angular distribution, appears in Table I.

TABLE I.

E_D kev	15	30	45	60	75	90	105
σ_{TD} barns	0.0154	0.28	1.0	2.2	3.6	4.6	4.94

σ_{TD} shows a peak at 107-kev E_D, with magnitude 4.95 barns, and at 25 kev has a Gamow coefficient of 19.35 $\log_{10}$ barns kev/kev$^{\frac{1}{2}}$ close to that of DD and to the theoretical value.

* Work performed under the auspices of the AEC.

B9. He^3D Cross Sections 35–100 kev.* J. L. TUCK, W. R. ARNOLD, J. A. PHILLIPS, G. A. SAWYER, AND E. J. STOVALL, JR., *Los Alamos Scientific Laboratory.*—Using 99 percent He^3 gas in the target chamber, the He^3D cross section has been measured at 25 points with 1 percent statistics and 6 percent estimated over-all accuracy counting alpha-particles. A selection of the cross sections calculated, assuming an isotropic angular distribution, appears in Table I. The Gamow plot is

TABLE I.

E_D kev	35	45	55	65	75	85	95
σ_{He^3D} millibarns	0.109	0.51	1.5	3.4	6.4	10.5	16.0

linear with slope 38.9 $\log_{10}$ barns kev/kev[1]. This is 2.01 times the DD slope measured previously in satisfying agreement with the theoretical value of 2. The deuteron energies cited above are sugject to a downward revision of a few hundred volts due to the energy loss in the He^3 gas. Appropriate energy loss cross sections are being measured using the same apparatus.

* Work performed under the auspices of the AEC.

B10. Photo Protons from Heavy Elements. W. E. STEPHENS AND M. E. TOMS, *University of Pennsylvania.**—The photoprotons ejected from bismuth, cerium, and barium by the 24-Mev bremsstrahlung from the University of Pennsylvania betatron have been measured in nuclear emulsions. Preliminary results give yields of approximately $16 \cdot 10^4$ and $23 \cdot 10^4$ protons per mole per roentgen unit for Ce and Ba, respectively. A second run with better statistics than our previous data gives $4 \cdot 10^4$ $p/m/r$ from bismuth. The yields calculated from an evaporation process are roughly $0.4 \cdot 10^4$, $0.07 \cdot 10^4$, and $0.09 \cdot 10^4$ $p/m/r$ for Bi, Ce, and Ba, respectively. The angular distribution of the bismuth photoprotons is markedly asymmetric with three times as many protons at 30° and 50° as at 130° and 150°. If these asymmetric protons are ascribed to a direct photoelectric effect, then at least half of the bismuth yield is due to such an effect. It would seem reasonable then to associate the high yields from Ce and Ba also with a direct effect. The angular distribution of the photoprotons from Ce and Ba will be measured to examine this further.

* Assisted by the Air Research and Development Command and by the joint program of the ONR and AEC.

MONDAY MORNING AT 10:00

University of Denver

(HARVEY FLETCHER presiding)

General Physics; Fluid Dynamics

C1. Utah Digital Computer.* D. C. EVANS AND W. M. ELSASSER, *University of Utah.*—Recent developments have made available machines of large arithmetical capacity which can be operated by an individual physicist. Our installation now consists of the digital differential analyzer made commercially by the Northrop Aircraft Corporation, and an input-output device constructed by us. The latter is operated automatically by the machine and uses punched paper tape as external memory. We are now supplementing these devices by a 10×10 size linear-secular equation solver (analog machine; expected accuracy 0.1 percent). The digital differential analyzer has a capacity comparing favorably with that of a very large mechanical analyzer; its accuracy is variable and directly proportional to running time. For typical problems and conventional three-digit accuracy, running time is of the order of some minutes. The arithmetical methods used in our devices are much closer to processes of traditional mathematical analysis than is the case for most digital machines; this feature makes it possible to operate these machines without the benefit of experts in numerical computing. Our experience to date has convinced us that the aim of a physicist to do his computing personally rather than to relay it to a separate organization can eventually be achieved.

* Supported by the Geophysics Division, Air Force Cambridge Research Center.

C2. A Table Model Computer for Fourier Synthesis. BARTON J. HOWELL.—An analog computer is described for Fourier synthesis using optical methods, and is discussed on the basis of its utility in computing the projection of crystal structures from x-ray data. The computed two-dimensional structure is recorded photographically. The instrument is based on the principles of the "multiple projector"[1] using "modified Huggins masks"[2] but differs in the methods of obtaining multiple light sources with individual intensity controls. The major advantages of this instrument are (a) its small size; (b) the reproducibility of all components in manufacture; (c) independence from ambient or permanent power conditions; and (d) ease of adjustment and rapid computations.

[1] Dan McLachlan, Jr., and Roscoe H. Woolley, Rev. Sci. Instr. **22**, 423 (1951).
[2] Howell, Christensen, and McLachlan, Jr., Nature **168**, 282 (1951).

C3. Kinks in Gases. GEORGE ANTONOFF.— As in solids and liquids kinks are also observed in gases. The value PV (pressure-volume) can be easily measured with five significant figures. Only three of them show themselves reproducible. To assure the last two figures the substance must be suitably conditioned. Change in properties with time may be observed, until the system reaches the equilibrium. The process is accelerated by impurities, such as water. In drastically dried systems (J. B. Baker) properties can be fixed for long. For reproducibility the impurities must be standardized and the time factor considered. The discrepancies observed are not due to inaccuracy in measurements.

C4. On the WKB Method. STANLEY C. MILLER, JR., AND R. H. GOOD, JR., *University of California, Berkeley.*—Ordinarily the WKB method is used both to demonstrate the classical limit of quantum mechanics and to obtain approximate solutions of the one-dimensional Schrödinger equation. At the expense of losing the classical limit demonstration, an improved approximation may be obtained. The usual procedure of substituting $\psi(x) = \exp i\hbar^{-1}[S_0(x) + \hbar S_1(x) + \cdots]$ into the Schrödinger equation and expanding for small $\hbar$ can be modified by using a more appropriate function than the exponential. For example, to discuss the Schrödinger equation for a potential well with two turning points, one can take, instead of the exponential, the functions arising in the harmonic oscillator problem, where the potential is of the same general type. There results an approximate wave function, continuous even across the turning points, which, far from the turning points, approaches the usual WKB function. The eigenvalue condition is identical with the ordinary WKB condition. The potential barrier problem can be treated similarly giving, for small penetration, the ordinary WKB transmission coefficient, but giving a different result for an energy near the peak of the barrier.

C5. Euclidean Tensors. WESLEY E. BRITTIN AND JAMES H. MARABLE, *University of Colorado.*—The n-dimensional Euclidean group $0(n)^1$ may be represented by the set of all matrices, E, of the form $\begin{bmatrix} 0(n) & t \\ 0 & 1 \end{bmatrix}$, $0(n)$ being an nxn orthogonal matrix, t an $nx1$ matrix, and 0 the $1xn$ zero matrix. E

may be considered as the matrix of a coordinate transformation relating two equivalent Euclidean frames of reference. Quantities defined in every frame and transforming under E as $ExEx\cdots xExE'^{-1}x\cdots xE'^{-1}xE'^{-1}$, a prime denoting the transpose, will be called Euclidean tensors. (A more modern definition would be based on an arbitrary representation of $0(n)$[1], but the present definition is sufficient for many applications and parallels the term, Cartesian tensor.) In certain applications where Euclidean relativity is required, the Euclidean tensors arise quite naturally. (In the pseudo-Euclidean space of special relativity $0(4)$ must be taken to be a Lorentz matrix.) Second-order skew-symmetric Euclidean tensors correspond to the motors of line geometry. An application to the dynamics of rigid bodies will be made, and the results compared with the corresponding but more complicated motor treatment.

C6. On the Phase Space of a Nonlocalizable Elementary Particle. E. J. SCHREMP, *Naval Research Laboratory*.—By considering the projective properties of the complex essential parameters q^1/q^0, q^2/q^0, q^3/q^0 of the proper Lorentz group (where $q=e_0q^0+e_1q^1+e_2q^2+e_3q^3$ is a general complex quaternion of norm Pe^{iS}), one may show that these parameters determine and are determined by two canonically conjugate quaternions $p=e_0p^0+i(e_1p^1+e_2p^2+e_3p^3)$, $x=e_0x^0+i(e_1x^1+e_2x^2+e_3x^3)$, with real coordinates p^k, $x^k(k=0, 1, 2, 3)$ in the tangent space T_4 to space-time (the corresponding rays through the origin of T_4 being equivalent, respectively, to the actual and ultra-infinite points of a real hyperbolic 3-space). These coordinates p^k, x^k have been identified with the external momentum and internal configuration variates of a single nonlocalizable elementary particle; and the real gauge P has been interpreted as the particle's coefficient of probability of phase $P(p;x)$, and the imaginary index S as the integral $\int(p\,d\bar{x}+dx\,\bar{p})$.[1] For $P>0$, the quaternion transformation $pq=\bar{q}e^{iS}$, $2x=(\bar{q}/\bar{q}^0)p-p(q/q^0)$ so determines p and x that their norms, $p\bar{p}=m^2(=1)$ and $x\bar{x}=-r^2$, are absolute and relative invariants, respectively (the only invariant constraint upon x^k, for $r>0$, being the null-polarity $p\bar{x}+x\bar{p}=0$). The inverse transformation, valid for $P\gtrless 0$, is $q/q^0=(\bar{x}/x^0)(e_0-pe^{\pm iS_0})$, where $\cos S_0=p^0-x^0$ and $q^0/\bar{q}^0=e^{i(S\mp S_0)}$.

[1] In taking the complex conjugate, denoted by the bar ($^-$), it is here understood that the quaternion units e_0, e_1, e_2, e_3 are real.

C7. Fast Jets from Collapsing Cylinders. F. J. WILLIG, F. A. LUCY, AND R. G. SHREFFLER.—A method is described for producing fast jets from the collapse of metal-line cavities in high explosives. The behavior of these jets suggests that they cannot be accounted for by the simple hydrodynamical considerations that have in the past been successful when applied to slower type jets. Various experiments, including time resolved spectrographic observations, show the jets to be, at least in part, of a gaseous nature. Velocities as high as 90 km/sec have been observed for beryllium jets, with heavier elements exhibiting lower velocities in inverse order of their atomic weights.

C8. A Study of Impinging Liquid Jets in a Liquid Stream. GEORGE G. KRETSCHMAR AND HENRY W. WEDAA, *Inyokern*.—Two miscible organic liquids are injected into a vertical tube containing the mixture of the two liquids. The volume ratio of injection is maintained constant by means of a positive displacement hydraulic injection equipment. The injector is of a fixed geometry as regards size of injector holes and the angle of impingement. A study of the mixing of the two liquids has been carried on by an optical method making use of a modified schlieren system. The liquid stream is in a round glass tube which is contained in a rectangular glass-sided cell filled with liquid of about the same index of refraction as the glass tube. This masks the refractive effect of the glass tube and much of the lens effect of the round cross section of the stream. It is shown that for a definite minimum energy of injection, the mixing becomes essentially complete at the end of the mixing region. The region of mixing appears in the photographs as a region of special turbulence above the jet openings, in which the jet energy is being dissipated.

C9. Dependence of Pfeifenton (Pipe Tone) Frequency on Pipe Length, Orifice Diameter, and Gas Discharge Pressure. A. B. C. ANDERSON, *Inyokern*.—When a pipe terminated in an orifice is attached to a large vessel containing gas, a spectrum of acoustic notes is produced inside the pipe as the gas pressure in the vessel is either raised or lowered. These notes differ from ordinary organ pipe notes in that they are produced in and by the gas discharging continuously from the orifice. Most studies related to this phenomena were made during the last century and the oscillations were then called *Pfeifentöne*. Measured dependences of the *Pfeifenton frequency* on static flow pressure, orifice diameter, and pipe length are presented here, based upon studies of air flowing through pipes terminated in various orifices. Frequency measurements were made of the vibrations inside the pipe. The *Pfeifentöne* are not a series of discrete single valued harmonics. Each covers a range of frequencies, any specific value of which is determined by the discharge flow-velocity or pressure. When the orifice diameter approaches zero the behavior of the *primary Pfeifenton* frequencies is as if they were produced by an open-closed organ pipe; when the orifice diameter approaches that of the pipe, the behavior is as if they were produced by an open-open organ pipe. A mechanism for the excitation of the *Pfeifentöne* is proposed.

C10. Analog Computation in a Theory for Critical Stability of a Fluid. F. T. ROGERS, JR., AND H. L. MORRISON, *Inyokern*.—Reference 1 derives two simultaneous linear differential equations in mixed variables and nonconstant coefficients, which, with suitable boundary conditions, define the thermal environment at critical stability of a fluid (heated from below) in a porous medium. It also presents a solution of the system as got by the beginning of successive approximations. At the suggestion of, and with the advice of, Dr. R. H. Olds, two limiting cases have been solved on the N.O.T.S. analog computer, one for $\nu=0$ and $\varphi=0$, the other for $\varphi=0$; notation is that of reference 1. Since the system represents a characteristic value problem, analog computation involved the automatic generation of dependent variables by the machine, for various values of the parameter whose characteristic value was sought. Examination of charts of generated dependent variables served to identify those forms which satisfied boundary conditions, and hence the desired characteristic value. We wish to report that for each limiting case above referred to, analog computation led to results which are essentially indistinguishable from those listed in reference 1.

[1] Rogers, Schilberg, and Morrison, J. Appl. Phys. **22**, 1476 (1951).

C11. Application of a Generalization of Heisenberg's Model of Turbulence to Critical Reynold's Numbers. E. N. PARKER, *University of Utah*.—It is possible to generalize the turbulence model proposed by Heisenberg for isotropic homogeneous turbulence fields, to the case of anisotropic inhomogeneous fields. Application of the resulting equations to computation of critical Reynold's numbers has been carried out on the belief that it poses a critical test of the model. In particular, the critical Reynold's number for flow through a pipe has been calculated and is found to agree with experiment. The somewhat more complicated problem of flow past a plate has been carried out, the results again being in agreement with experiment and results obtained by Lin[1] and others directly from the Navier Stokes equations. The advantage of the model is, first, the ease with which results may be obtained, and

second, the clear physical insight afforded by the simple calculations involved.

[1] C. C. Lin, Quart. Appl. Math. **3**, 117, 218, 277 (1945).

C12. Scabbing of Metals Under Explosive Attack: Multiple Scabbing.* JOHN S. RINEHART, *Inyokern.*—Further quantitative data bearing on the scabbing of metals under explosive attack are presented in this paper. In particular, the mechanics of the generation of multiple scabs is established. Experimental data have been obtained that show that multiple scabbing will occur whenever the maximum stress σ_0 in the transient wave that impinges on a free surface is more than double the critical normal fracture stress σ_c of the material. The number of scabs that will be formed will be equal to the first whole number smaller than the quotient σ_0/σ_c. The thickness of each scab is governed by the shape of the stress wave.

* Work supported by Armament Branch, ONR.

C13. Rayleigh Disk Measurements in He^3–He^4 Mixtures. JOHN R. PELLAM, *National Bureau of Standards*, AND BERNARD WEINSTOCK, *Argonne National Laboratory.*—Observations of second sound propagation in a four percent mixture of helium 3 in helium 4 have been carried out. Both wave velocity and mechanical energy density of second sound waves have been observed by means of the disk in the temperature range from 2°K down to 0.9°K. Our extension of measurements beyond the range of Lynton and Fairbank[1] (0.8 percent of He^3 concentration and down to 1.2°K) have shown no decrease in velocity as predicted by Pomeranchuk;[2] rather for this new region the velocity tends to rise even more rapidly down to the lowest temperatures reached (about 38 m/s at 0.9°K) as predicted by Dingle.[3] The prediction of Koide and Usui[4] that torque on the Thermal Rayleigh disk would drop markedly (for constant heat current) has been confirmed. Our observations show that at 0.9°K, for example, the presence of 4 percent helium 3 decreases the mechanical energy density (and thus the torque) from the pure helium 4 value by more than two orders of magnitude.

[1] E. Lynton and H. Fairbank, Phys. Rev. **80**, 1043 (1950).
[2] L. Pomeranchuk, J. Exptl. Theoret. Phys. USSR **19**, 42 (1949).
[3] R. Dingle, Phil. Mag. **42**, 1080 (1951).
[4] S. Koide and T. Usui (to be published).

MONDAY AFTERNOON AT 2:00

Cosmopolitan

(W. W. HAVENS presiding)

Neutrons and General Nuclear Physics; Positronium

D1. Inelastic Scattering of 7.7-Mev Protons.* J. A. HARVEY,† *M.I.T.*—Inelastic protons have been observed from targets (several mg/cm² thick) bombarded with 7.7-Mev protons from the M.I.T. cyclotron. The inelastic proton spectra were measured with aluminum absorbers and previously described equipment.[1] The following targets have been studied: lithium, beryllium, carbon, fluorine (Teflon), sodium, magnesium, aluminum, calcium, titanium, vanadium, nickel, and zirconium. For the targets where excited levels are already known the inelastic proton groups agreed with the known levels. The first excited level observed in Ca^{40} occurred at 3.8 Mev. Angular distributions of the inelastic proton groups are approximately isotropic over the angles studied. The inelastic protons from the 1.38-Mev level in Mg^{24} have also been measured with 5.9- and 6.8-Mev protons and the angular distributions vary with energy. Cross sections of the inelastic protons have been measured relative to the elastically scattered protons from a thin gold target. The total cross sections range from 200–500 mb except for vanadium which is only 40 mb. This is probably due to the low (p, n) threshold of vanadium.

* Supported in part by the ONR and AEC.
† Now at Brookhaven National Laboratory.
[1] Boyer, Gove, Harvey, Deutsch, and Livingston, Rev. Sci. Instr. **22**, 311 (1951).

D2. Neutron-Proton Scattering Using Organic Crystal Scintillation Detectors.* M. E. REMLEY,† W. K. JENTSCHKE, AND P. G. KRUGER, *University of Illinois.*—Organic scintillation crystals of anthracene and stilbene have been used as both a source and detector of recoil protons to investigate the angular distribution of protons recoiling from fast neutrons. Neutrons of 13.7 and 28.4 Mev were obtained from the $D(d, n)He^3$ and $T(d, n)He^4$ reactions with deuterons accelerated by the University of Illinois cyclotron. The amplified output of a 5819 photomultiplier was analyzed with a twelve channel pulse amplitude analyzer. Using the known pulse height *vs* energy relation for protons incident on the crystals, the data were converted to angular distributions. The corrections required for the finite size of the crystals were calculated and applied to the data. The angular distribution obtained at 13.7 Mev is consistent with spherically symmetric scattering in the center-of-mass system, while the results at 28.4 Mev show an anisotropy with a favoring of scattering in the backward direction. This anisotropy appears somewhat greater than that predicted by Christian and Hart,[1] using a Yukawa potential with exchange forces plus the inclusion of a tensor force. However, the results are consistent with previously reported results at 27 Mev.[2]

* Assisted by the joint program of the ONR and AEC.
† Now at North American Aviation, Inc., Downey, California.
[1] R. W. Christian and E. W. Hart, Phys. Rev. **77**, 441 (1950).
[2] Brolley, Coon, and Fowler, Phys. Rev. **82**, 190 (1951).

D3. Total Cross Sections for 14-Mev Neutrons. J. H. COON, E. R. GRAVES, AND H. H. BARSCHALL, *Los Alamos Scientific Laboratory.*—The total cross sections of over 50 elements were measured for 14-Mev neutrons in a geometry in which the effect of scattering through angles greater than 2° was observed. A plot of the square root of the total cross sections *versus* the one-third power of the atomic weight shows deviations from the linear relationship predicted by statistical theory.[1] The deviations are most pronounced for low and high atomic weights.

* Work performed under the auspices of the AEC.
[1] H. Feshbach and V. F. Weisskopf, Phys. Rev. **76**, 1550 (1949).

D4. Response of Organic Crystals to Neutrons. T. W. BONNER, A. B. LILLIE AND H. L. TAYLOR, *Rice Institute.*—Recoil-protons from monoenergetic neutrons have been observed in anthracene, stilbene, terphynl, and diphenylacetylene crystals. The ratio of pulse sizes from 580-kev recoil-protons in these crystals has been compared to that from 660 kev gamma-radiation. The largest proton pulses relative to gamma-ray pulses were observed in anthracene;

the other crystals followed in the order of stilbene, terphynl, and diphenylacetylene. 60-kev recoil-protons from threshold neutrons of the reaction $H^3(p,n)He^3$ were observed in an anthracene crystal. 1.5-Mev carbon recoils from 4.5-Mev neutrons were also detected in anthracene.

D5. The Two-Plate Method of Measuring Anisotropic Fast Neutron Spectra.* JOHN E. EVANS, *Los Alamos Scientific Laboratory.*†—Anisotropic, as well as isotropic, fast neutron spectra can be measured by exposing two nuclear plates in planes 90° apart. In plate No. 1 tracks $\leq 45°$ (unprocessed emulsion) from the emulsion plane are measured at all azimuth angles. In plate No. 2 tracks are measured if their directions fall in the supplementary double cone. The sum of tracks from equal volumes of both plates constitute all proton recoils which originate in that volume of emulsion and the formula of Reines[1] gives the neutron density spectrum. No tracks with angles $>45°$ from the emulsion plane must be measured. Small length corrections[2] (0 to 7 percent) must be made to tracks between 25° and 45° from the emulsion plane, since the track shrinkage differs from the emulsion shrinkage at these angles. By measuring tracks which start in the central 20-micron layer in a 200-micron emulsion spectra can be measured from 600 kev to 4.1 Mev. 1050 tracks have been measured from a pair of plates exposed to two groups of monoenergetic neutrons about 500 kev apart. Two well separated peaks were obtained.

* Work done under the auspices of the AEC.
† Present Address: Phillips Petroleum Company, Idaho Falls, Idaho.
[1] F. Reines, Phys. Rev. **74**, 1565 (1948).
[2] J. Rotblat and C. T. Tai, Nature **A164**, 835 (1949).

D6. Mirror Measurement of the Neutron-Electron Interaction. D. J. HUGHES, J. A. HARVEY AND M. D. GOLDBERG, *Brookhaven National Laboratory.**—In the method[1] of measurement of the neutron-electron interaction by reflection of neutrons from a bismuth-liquid oxygen interface, the principal uncertainties arise from the measured values of the critical angle and the free atom cross sections of bismuth and oxygen. The accuracy of the critical angle measurement has now been improved to the extent that the uncertainty in the well depth (now 4250 volts) of the interaction from this source is only 250 volts. The present values of the bismuth and oxygen free atom cross sections, based on separate transmission measurements for each element, contribute a somewhat larger error. Because the difference of the oxygen and bismuth scattering amplitudes enter the expression for the critical angle, only the *relative* transmissions are needed accurately. The relative transmissions are now being measured by a self-monitoring method, involving two pile beams, in which high counting rates can be used with no dead-time correction. The present 4250-ev result may change slightly but the final error, including all uncertainties, will be about 400 ev. When 4100 ev for the Foldy effect (magnetic dipole interaction) is subtracted, the mesonic effect is extremely small.

* Research carried out under contract with the AEC.
[1] Harvey, Hughes, and Goldberg, Bull. Am. Phys. Soc. **27**, No. 3, 44 (1952).

D7. The Paramagnetic Neutron Scattering Cross Section of Various Transition Group Ions at Long Neutron Wavelengths.* R. R. SMITH, *Columbia University and Brookhaven National Laboratory*, AND T. I. TAYLOR AND W. W. HAVENS, JR., *Columbia University.*—The paramagnetic neutron-scattering cross section has been determined for the following ions; Fe^{+++} in FeF_3 and $ZnFe_2O_4$, and Mn^{++} in MnF_2 and MnO. Because of the high intensity of subthermal neutrons available from the Brookhaven reactor, it was possible to carry out measurements at neutron wavelengths long enough for the paramagnetic scattering to become isotropic. For this limiting condition, theory indicates a cross section of 21 barns per ion for uncoupled paramagnetic ions.[1] Such was found to be the case with FeF_3, $ZnFe_2O_4$, and MnF_2. The cross-section variation with wavelength found for the Mn^{++}-ion in MnF_2 was in excellent agreement with the theoretical.[1] The paramagnetic scattering of the Mn^{++}-ion in MnO behaves differently. Because the electron spins are partially coupled in this compound, many of the collisions will be inelastic. Thus, instead of a form factor increase of scattering with wavelength a $1/v$ dependence is to be anticipated. This was found to be the case. The lattice vibrational inelastic scattering was estimated from slight $1/v$ dependences of the experimental curves at wavelengths long enough for the paramagnetic contribution to be constant.

* Research carried out under AEC contract with Columbia University.
[1] O. Halpern and M. H. Johnson, Phys. Rev. **55**, 898 (1939).

D8. Nuclear Relaxation Time of Hydrogen Gas. MARTIN E. PACKARD, *Varian Associates*, AND HARRY E. WEAVER, *Stanford University.*—The nuclear relaxation time T_2 of hydrogen gas has been measured as a function of pressure over the range of $\frac{1}{3}$ atmosphere to 40 atmospheres. The data below 3 atmospheres was taken by measuring the nuclear magnetic resonance line width as recorded by a phase sensitive detector. The data above 4 atmospheres was obtained from a direct line-width measurement recorded photographically from an oscilloscope having a very slow sweep. This data was corrected for the broadening effects of the magnet. Spin echo measurements of T_1 were made at the higher pressures and were found to agree within experimental error to the line width measurements of T_2 at the same pressures. The relaxation time T_2 is found to be almost directly proportional to the pressure[1] and to have as representative values a T_2 of $(1.0\pm0.2)\times10^{-4}$ second at 1 atmosphere, and $(1.2\pm0.2)\times10^{-3}$ second at 10 atmospheres.

[1] N. Bloembergen, *Nuclear Magnetic Relaxation* (Martinus Nijhoff, 1948), p. 103.

D9. The Roughness of the Nuclear Energy Surface. JOHN A. ELDRIDGE AND RICHARD J. BRUNDY, *State University of Iowa.*—When a proton or neutron is added to a nucleus the binding energy (*B.E.*) of the two particles differ because they differ in mass, because they change the isotopic number oppositely, and because of a specific preference for certain proton and neutron numbers (p, n). By allowing for the first two effects we obtain values (D_2) which show the depression increments (in Mev) of the energy surface of the nuclides below a smooth parabolic valley. As typical, values are given for two particular nuclide chains along the energy surface.

	H^1	H^2	H^3	He^4	He^6	Li^6	Li^7	Be^8
(p,n)	(1,0)	(1,1)	(1,2)	(2,2)	(2,3)	(3,3)	(3,4)	(4,4)
ΔD_2		−17	12.7	14.1	3.2	1.7	9.5	15.6
B.E.		2.18	6.2	19.8	−0.8	4.5	7.2	17.2

	N^{14}	O^{15}	O^{16}	F^{17}	F^{18}	F^{19}	F^{20}	Ne^{21}
(p,n)	(7,7)	(8,7)	(8,8)	(9,8)	(9,9)	(9,10)	(9,11)	(10,11)
ΔD_2	10.6	13.2	3.2	6.7	9.8	7.6	12.6	
B.E.	7.3	15.6	0.51	9.1	10.3	6.4	13.0	

The consistently larger (underlined) values of D_2 when either p or n changes from odd to even show the effect of pairing.

D10. A New Conception of Nuclei and Elementary Particles. ENOS E. WITMER, *University of Pennsylvania.*—The masses of nuclei and elementary particles in all states are given by Mm, where m is the rest mass of the negative electron and M is a rational number. For this reason the writer has proposed the idea[1] that there are no particles in the nucleus. Fundamentally the nuclei and so-called elementary particles are on a par. To explain the good results obtained with individual particle models, we propose a *new correspondence principle*, according to which an individual particle model of any assumed compound structure of nuclear character may give good results in many respects whenever the transition to

a state in which any of the assumed constituent particles exist in the free state does not involve neutrinos. It seems reasonable to add the requirement that the binding energy per particle in the assumed compound structure shall be only a small fraction of the rest mass of the assumed constituent particles. This principle rules out electrons as satisfactory constituent particles, but not protons, neutrons, and alpha-particles. In any case such an assumed particle model is only an approximation to what actually exists.

[1] E. E. Witmer, Bull. Am. Phys. Soc. **27**, No. 3, Abstract SP2, Washington Meeting, 1952.

D11. The Use of Annihilation of Positrons in Flight to Give a Peaked Gamma-Ray Spectrum. STIRLING A. COLGATE, *University of California, Berkeley.*—The theoretical behavior of the annihilation of positrons in flight with a negative electron at rest was derived by Dirac.[1] The total cross section at high energy is qualitatively checked by the experiment (above), so that the theoretical gamma-ray spectrum can be relied upon. This spectrum is strongly peaked at the high and low energy ends. In one-half the annihilation events, one of the two gamma-rays has an energy greater than $E-E/\{\pi[2/(E+1)^{\frac{1}{2}}]\}$ where E is the total energy of the positron. The spectrum of annihilation plus bremsstrahlung for positrons passing through low Z materials is favorable from 10 Mev up to 200 Mev for threshold type experiments. 10-Mev positrons passing through $\frac{1}{4}$ cm of LiH will give an annihilation spectrum peak 10 percent (full width and 50 times the intensity of the upper 10 percent) of the bremsstrahlung spectrum. 200-Mev positrons passing through 1/100 radiation lengths (30 cm) of liquid hydrogen give a peak 6 times the bremsstrahlung intensity and 3 percent wide.

[1] P. A. M. Dirac. Proc. Cambridge Phil. Soc. **26**, 361 (1930).

D12. The Annihilation of Positrons in Flight at 100 and 200 Mev. F. C. GILBERT AND STIRLING A. COLGATE, *University of California, Berkeley.*—The two disappearances observed by Gilbert *et al.*[1] of 200-Mev electrons in flight in nuclear emulsion prompted the following investigation by counters of the general question of the annihilation in flight of positrons and electrons. A poor geometry absorption experiment was performed in Be and LiH in absorbers thin compared to the processes multiple scattering, single scattering, and bremsstrahlung. Three small proportional counters in a magnetic field determined the momentum of electrons or positrons from a radiator in the bremsstrahlung beam of the Berkeley synchrotron. A fourth large counter backed up a small absorber and by anticoincidence indicated the absorption of the particle. The cross section for the theoretically known process of annihilation in flight by positrons at 200 Mev agreed with theory ±25 percent. This cross section is $\frac{1}{4}$ that corresponding to the two events observed in nuclear emulsion above. The disappearance of electrons in flight at 200 Mev was $\frac{1}{4}$ the positron annihilation cross section and corresponded to the approximate bremsstrahlung loss. At 100 Mev, positron annihilation doubled in agreement with theory and electron disappearances were the same. Better statistics are anticipated.

[1] Violet, Gilbert, Deutsch and Barkas, Phys. Rev. **85**, 756 (1952).

D13. Magnetic Quenching of the Three-Quantum Annihilation of Positronium. OTTO HALPERN, *University of Southern California.*—Observations on the change in the number of three-quantum processes of annihilation of positronium in a constant magnetic field have been reported by Deutsch and Dulit[1] and recently in a summary form by Wheatley and Halliday.[2] The theory of this quenching process has been extended to include the assumption that transitions between the three states of ortho-positronium are produced by collisions with a rate that is not vanishingly small as compared with the various rates of annihilation. This refinement of the theory may be required to account for the observation[3] that the number of three-quantum processes decreases to one-half of its original value for large magnetic fields. We have also worked out a more detailed theory for the influence of an additional alternating magnetic field;[4] formulas for the determination of the splitting of the energy-levels of para- and ortho-positronium[4] and a comparison with the experiments[3] will be presented.

[1] M. Deutsch and E. Dulit, Phys. Rev. **84**, 601 (1951).
[2] J. Wheatley and D. Halliday, Bull. Am. Phys. Soc. **27**, 59, Y4 (1952).
[3] M. Deutsch and S. C. Brown, Phys. Rev. **85**, 1047 (1952).
[4] A. Klein and R. Karplus, Bull. Am. Phys. Soc. **27**, 59, Y3 (1952).

MONDAY AFTERNOON AT 2:00

University of Denver

(E. J. WORKMAN presiding)

Electronic and Solid-State Physics

E1. On the Relation Between the Conductance and the Noise Power Spectrum of Certain Electronic Streams. J. J. FREEMAN (*introduced by* Harold Lyons).—The noise power spectrum of a diode with a temperature-limited current and also for a diode with a retarding field is shown to be the sum of two parts. One, the "pure" shot effect, is the spectrum that would obtain if the electrons were all emitted with zero velocity, that is, if the cathode were at zero temperature (and still maintained the same emitting properties). The second is the thermal contribution; namely, $4kTg$, where T is the cathode temperature and g is the conductance of the electron stream.

E2. Notes on a Radiofrequency Mass Spectrometer. JAMES C. AXTELL,* EMMETT H. WILEY,† AND S. W. BASS, *Texas College of Arts and Industries.*—Using a design based on a modification of the ion mobility apparatus of Tyndall and Powell,[1] the authors have constructed a radiofrequency mass spectrometer which has been able to separate the isotope of neon of atomic weight 22, with an over-all ion current of 100 milliamperes (measured at the source). The total through-put of the spectrometer was only 10 microamperes, showing an ion efficiency of only 0.01 percent. The device shows considerable promise of serving as an efficient isotope separator.

* Now at Southwest Research Institute.
† Now at General Electric Research Laboratory.
[1] Tyndall, Starr, and Powell, Proc. Roy. Soc. (London) **A121**, 172 (1928).

E3. The Range-Energy Relation for Heavy Ions. P. M. STIER AND G. E. EVANS, *Oak Ridge National Laboratory.*—The extrapolated ionization ranges of a number of heavy positive ions (H^+, He^+, N^+, Ne^+, N_2^+, and A^+) have been measured in a number of stopping gases (He, N_2, A, and air), at energies from about 50 to 300 kev. A monoenergetic beam of heavy ions

from a Cockcroft-Walton accelerator enters the range chamber by passing through three 0.030-inch pinholes, which form a highly collimated beam and act as barriers for a differential pumping system. Ionization-range data were obtained by using a movable parallel plate ionization chamber, 3 inches in diameter, whose "entrance foil" was a high transparency grid. For a majority of the incident ion-stopping gas combinations studied, the range-energy curve is approximately linear. It has been found that the range is not exactly inversely proportional to the pressure. An interpretation of this "pressure effect" based upon elastic scattering and geometrical factors, is proposed which accounts for the observed effects without recourse to any postulates concerning the mechanism of ionization.

E4. Space Distribution of Ionization. G. E. EVANS AND P. M. STIER, *Oak Ridge National Laboratory.*—The space distribution of ionization produced by a beam of positive ions entering a gas volume has been measured, using the same incident ions, stopping gases, and energies described in preceeding abstract. Relative ionization density was measured as a function of axial distance (R) and radial distance (r) using a small (*ca* 1 mm³) ionization chamber, eccentrically mounted so as to permit motion in three dimensions. Integration of ionization density data over planes normal to the beam axis yields results in good agreement with previously measured ionization range curves. Empirical relations have been established between relative ionization density, axial distance (R), radial distance (r), and pressure. It has been found that the axial attenuation of the ionization is approximately exponential, whereas the radial attenuation is approximately Gaussian. This is in qualitative agreement with the behavior to be expected if the primary mechanism of energy transfer is by elastic scattering.

E5. Measurements of Ionization Efficiencies. WILLARD H. BENNETT, *Naval Research Laboratory.*—The nonmagnetic mass spectrometer[1] is being applied to the measurement of ionization efficiencies for multiple ionization. All voltages throughout the tube are held constant except the voltage through which the ionizing electrons are accelerated in the ion source. The various orders of ionization are separately measured by varying the frequency only of the rf potential used in the mass spectrometer. It can be shown when all voltages in the analyzer of the mass spectrometer are held constant, that the small deviations from a straight line path through the tube for any charge-to-mass ratio, when the appropriate frequency of the rf potential is applied to enable that charge-to-mass ratio to reach the collector, are identical with those for any other charge-to-mass ratio at its appropriate frequency. For this reason the instrument used in this way permits the relative ionization efficiencies for the different orders of ionization to be measured free of the errors that are unavoidable in any method requiring the use of slits.

[1] J. Appl. Phys. **21**, 143 (1950).

E6. Efficiencies of Multiple Ionization of Mercury. BOYD W. HARNED AND WILLARD H. BENNETT, *Naval Research Laboratory.*—The relative efficiencies of multiple ionization of mercury vapor have been measured using the nonmagnetic mass spectrometer for electron energies up to 5 kilovolts. The total ionization as a function of ionizing electron energy has the same form as the results published by Compton and Van Voorhis,[1] P. T. Smith,[2] and J. W. Liska[3] but disagrees with the results of W. Bleakney,[4] as do the results of the others. The ion currents for each order of ionization also differ from the results of Bleakney in a similar manner, being smaller than Bleakney's at low voltages and larger at high voltages. An explanation for the discrepancy will be suggested.

[1] Compton and Van Voorhis, Phys. Rev. **27**, 724 (1926).
[2] P. T. Smith, Phys. Rev. **37**, 814 (1931).
[3] J. W. Liska, Phys. Rev. **46**, 169 (1934).
[4] W. Bleakney, Phys. Rev. **35**, 139 (1930).

E7. Total Specific Ionization in Air, Argon, and Hydrogen from 17.5-Mev Electrons. J. OVADIA, J. S. LAUGHLIN, J. W. BEATTIE, AND W. J. HENDERSON, *University of Illinois.*—The total specific ionization produced in air, argon, and hydrogen by a beam of monoenergetic electrons whose kinetic energy was varied from 9.0 to 17.5 Mev has been measured. The electrons were accelerated in a betatron, and the energy was varied by controlling the expansion time. An absolute energy calibration was obtained by observing known electrodisintegration thresholds. A thin lens magnet focused the electrons into a nearly parallel beam of 3-mm diameter, which then passed through a parallel plate ionization chamber and into a Faraday cage. Guard electrodes insured the uniformity of the collecting field in the chamber. The electron and ion currents were amplified in dc current amplifiers and their absolute values read directly. The ratio of these currents together with a knowledge of the pressure, temperature, and path length of the electrons in the chamber yields the total specific ionization. The total specific ionization in air and hydrogen was found to increase by 5 percent when the kinetic energy of the electron is raised from 9 Mev to 17.5 Mev. The following values of the total specific ionization produced by 17.5-Mev electrons were obtained in these gases: air, 64; argon, 101; hydrogen, 8.4; all the values are in ion pairs per cm at NTP.

E8. Average Energy Loss per Ion Pair of Slow Electrons in Helium. C. E. NIELSEN, *Ohio State University;* R. H. FROST, *University of Missouri;* AND W. J. CHOYKE, *Ohio State University.*—Either total or specific ionization produced by a low energy electron in an expansion chamber can, under suitable conditions, be obtained by the count of drops formed on the diffused ions. We have determined from a count of drops per cm of path the specific ionization of electron tracks of β from 0.3 to 0.8. Momentum was determined from measurements of curvature in a magnetic field perpendicular to the camera axis. From these results and application of the Bethe-Bloch theory one obtains a value of 26 ev per ion pair in He. We have determined from count of the number of drops per cluster the total ionization in ion clusters produced by x-ray photoelectrons of known energy. The preliminary value of average energy loss is 25 ev per ion pair.

E9. New Data on Electrical Phenomena Associated with the Freezing of Dilute Aqueous Solutions. MARVIN E. BACKMAN, *Inyokern.*—It was discovered by Workman and Reynolds[1] that electrical phenomena accompany the freezing of dilute aqueous solutions of ionic compounds. The exact nature of the effect is unknown and in order to obtain further information on the effect a study has been made of the dependence of the shape and magnitude of these curves on the concentration of the solute. A set of curves was obtained for a range of concentrations from 10^{-6} normal to 10^{-3} normal. The equipment used was the same electrometer apparatus used for earlier[2] investigation of the effect. Special techniques in the handling and preparation of solution were used to avoid CO_2 contamination.

[1] E. J. Workman and S. E. Reynolds, Phys. Rev. **78**, 254 (1950).
[2] M. E. Backman, Phys. Rev. **85**, 759 (1952).

E10. Lifetime of Injected Carriers in Germanium.† D. NAVON, RALPH BRAY, AND H. Y. FAN, *Purdue University.*—The lifetime of carriers injected into germanium samples by the application of square voltage pulses across the rhodium plated ends has been measured. The decay of conductance of

the sample from its value just after applying the pulse to its pre-pulse value is observed on an oscilloscope. An analysis of this curve gives a value for the lifetime of the injected carrier. Using this method, the variation of lifetime with sample dimension and surface condition was studied for holes injected into a 19 ohm-cm single crystal of N-type Ge. The recombination velocity[1] for the ground surface was $\sim 10^4$ cm/sec. The etched surface lifetime was a few hundred microseconds and showed no significant variation when the cross section was decreased from 0.74×0.37 cm down to 0.48×0.06 cm, indicating that a bulk lifetime was measured. The surface recombination velocity should be <100 cm/sec, much lower than values previously reported.[1] Tests were made on the effects of quenching from temperatures of 500°C and above. Many-fold changes in bulk lifetime were observed before the electrical resistivity was noticeably increased. Additional heat treatment results will be discussed.

† Supported by Signal Corps Contract.

[1] Shockley, *Electrons and Holes in Semiconductors* (D. Van Nostrand Company, Inc., New York, 1950), pp. 321, 324.

E11. Alpha-Particle Bombardment of PbS Semiconductors. F. K. ODENCRANTZ, *Inyokern.*—The conductivity of a thin film of PbS was measured during bombardment with polonium α-particles. The conductivity initially increased several percent and then decreased slowly to about one-third of its initial value. Recovery of the PbS after bombardment required several days. Conductivity *vs* bombardment time curves show a temperature dependence.

E12. Anomalous Paramagnetism of Copper Sulfate Pentahydrate. W. E. HENRY, *Naval Research Laboratory.*—The magnetic moment of an aggregate of quantized, noninteracting paramagnetic ions can be represented[1] as a function of (H/T), where H and T are the magnetic field and absolute temperature. Previous work[2] has shown that the Brillouin function very closely represents the magnetic moment for Cr^{+++} in potassium chromium alum (free spin) and Fe^{+++} in iron ammonium alum (free ion) in the range near magnetic saturation. The same experimental technique has been employed to study, at fixed temperatures in the helium range, the magnetic field dependence of the state of magnetization of Cu^{++} in one sample of crystalline copper sulfate pentahydrate. Observations were made for magnetic fields ranging from 3 to 50 kilogauss. When relative moments are plotted against H/T, curves drawn through experimental points for different values of T do not superimpose. This implies that the magnetic moment is not a unique function of (H/T). The apparent anomaly is examined in terms of possible[3] effects of crystalline field splitting, dipole-dipole, exchange and nuclear interactions.

[1] J. H. Van Vleck, *Electric and Magnetic Susceptibilities* (Oxford University Press, London, 1932), p. 257; L. Brillouin, J. Phys. (U.S.S.R.) **8**, 74 (1927).
[2] W. E. Henry, Phys. Rev. **85**, 487 (1952); Bull. Am. Phys. Soc. **27**, No. 1, 53 (1952); **27**, No. 3, 53 (1952).
[3] K. S. Krishnan and A. Mookherji, Phys. Rev. **54**, 533 (1938); Bagguley, Griffiths, and Price, Nature **162**, 538 (1948); R. D. Arnold and A. F. Kipp, Phys. Rev. **75**, 1199 (1949); T. H. Geballe, Ph.D. dissertation, University of California, 1950.

E13. Low Temperature Thermal Expansion of Uranium.* HENRY L. LAQUER AND ADAM F. SCHUCH, *Los Alamos Scientific Laboratory.*—The length changes of a number of samples of polycrystalline uranium have been measured between room temperature and various fixed low temperatures, using a dial gauge dilatometer. It appears that uranium has a density maximum somewhere between 20° and 60°K. Certain speculative explanations of this rather anomalous behavior are offered.

* Work performed under University of California contract with the AEC.

E14. Mathematical Studies of Thermal Processes Relating to Reaction Rates in Solid Fuels. R. H. OLDS AND G. B. SHOOK, *Inyokern.*—With the aid of a differential analyzer the equation,

$$k\frac{d^2T}{dx^2}+\rho cv\frac{dT}{dx}+I_0\alpha e^{-\alpha x}+\rho Hse^{-E/RT}=0,$$

describing the dependence of temperature upon heat transfer by thermal diffusion, radiant absorption, and chemical action, is being investigated for conditions representative of steady-state burning of solid fuels in rocket motors. Values for the physical and chemical parameters are estimated from experimental data, considerable uncertainty being introduced by extrapolation of the data to conditions assumed to prevail at the burning surface. The primary objective of the mathematical study is to determine the ranges of values for the physical and chemical parameters that yield solutions to the above equation in accordance with the observed behavior of solid fuels. The results so far are proving useful in revealing the relative importance of the various parameters so as to guide research toward the investigation of the more significant factors.

E15. Measurement of Reaction Rates for Solids. G. B. SHOOK AND R. H. OLDS, *Inyokern.*—A rapid method has been developed for determining the constants s and E in the Arrhenius term $s\exp(-E/RT)$ describing the temperature dependence of chemical reactions. The method is limited in the present apparatus to solids in which the reaction is not primarily dependent on a diffusion process, although a correction may be easily applied for low diffusion rates. The apparatus consists of a flow chamber containing the sample, a difference thermocouple providing a control signal to a heater linked to a servo system, a thermocouple providing a signal to a recording potentiometer, and a sweep gas metering and heating system. The sample is allowed to change temperature adiabatically or with a predetermined departure from adiabaticity. Temperature control is effected through the sweep gas passing through the flow chamber, the gas being maintained at, or a given incremental amount different from the temperature of the sample. The corrected rate of temperature change is then interpreted to represent the rate of chemical reaction in the sample. The usable range in rate of temperature change is at present approximately 0.001°C/sec to 2°C/sec. Typical data obtained for the thermal decomposition rate of organic nitrates are presented.

MONDAY AFTERNOON AT 2:00

Shirley-Savoy

(C. D. ANDERSON presiding)

Invited Papers

F1. Experiments on Penetrating Cosmic-Ray Showers. V. H. REGENER, *University of New Mexico.* (30 min.)

F2. Thunderstorm-Precipitation Growth and Electrical-Charge Generation. S. E. REYNOLDS, *New Mexico Institute of Mining and Technology.* (30 min.)

F3. A Review of Tropospheric Propagation Data at Distances Far Beyond the Horizon. G. R. CHAMBERS, *National Bureau of Standards, Boulder.* (60 min for F3-F4-F5 altogether.)

F4. Recent Developments in the Theory of Electromagnetic Wave Propagation through Spherically Stratified Media. J. FEINSTEIN, *National Bureau of Standards, Washington.*

F5. The Effect of Scattering by a Turbulent Atmosphere on the Received Field Deep in the Shadow Region. H. STARAS, *National Bureau of Standards, Washington.*

MONDAY EVENING AT 8:30

Cosmopolitan

(J. A. WHEELER presiding)

Invited Paper

G1. Physics and Atomic-Bomb Tests. A. C. GRAVES, *Los Alamos Scientific Laboratory.* (50 min.)

TUESDAY MORNING AT 9:30

Cosmopolitan

(J. W. BROXON presiding)

Apparatus of Nuclear Physics; Mesons

H1. Internal Absorption of Fluorescent Light in Large Plastic Scintillators.* C. N. CHOU, *University of Chicago.*—The preparation and performance of comparatively small plastic scintillators have been reported by several authors.[1] In a series of experiments large plastic scintillators were constructed; the samples had the form of a rod 3.5 cm in diameter and 20 cm long. These samples were compared with liquid phenylcyclohexane solution (plus 0.3 percent *p*-terphenyl and 0.001 percent diphenylhexatriene) of the same dimensions. The pulse-sizes were observed in an oscilloscope from the output of a 5819 photomultiplier attached to one end of the sample. Radiation from a Co^{60} source passed through the sample perpendicularly to its axis. A sample of anthracene in polystyrene of diameter 4.1 cm and as long as 30 cm showed relatively small absorption (within about 15 percent) of light output throughout the whole length. This makes it possible to use scintillators of this kind in cosmic-ray counter telescopes, for triggering cloud chambers and for locating weak radioactive sources, etc. Pyrene in polystyrene was found to be almost as good as anthracene in polystyrene for small thicknesses; however, it showed greater absorption at greater lengths. With the 130-Mev mu-meson beam of the Chicago cyclotron no saturation occurred for the plastics up to twice minimum ionization. Measurements in the proton beam of the cyclotron are in progress, in order to study the saturation effect at higher ionization losses.

* Supported by the joint program of the ONR and AEC.

[1] M. G. Schorr and E. C. Farmer, Phys. Rev. **81**, 891 (1951); W. S. Koski, Phys. Rev. **82**, 230 (1951).

H2. The Minimum Temperature Gradient Required for the Formation of Tracks in a Cloud-Ion Chamber. H. L. MORRISON AND G. J. PLAIN, *Inyokern.*—The radial and vertical distribution of temperature in a cylindrical diffusion cloud chamber (filled with air and 95 percent ethyl alcohol vapor at atmospheric pressure) has been determined during operation by reading twenty-two copper constantan thermocouples supported by a light Bakelite framework. Readings were taken at regular time intervals, beginning with the addition of the solid CO_2, through thermal equilibrium, and until the chamber had ceased to operate upon the depletion of the refrigerant. The vertical temperature gradient in the sensitive volume (the lower one-third of the chamber) was found to be approximately 13°C/cm during thermal equilibrium. Tracks were no longer visible when the gradient had diminished to 9.7°C/cm. It is therefore concluded that a gradient of at least 10°C/cm is required for the formation of tracks. The addition of heat to the top of the chamber has negligible effect on the vertical temperature gradient in the bottom third of the chamber, and hence changes the depth of the sensitive volume only slightly. There appears to be no appreciable horizontal temperature gradient.

H3. Low Pressure Helium Diffusion Cloud Chamber. W. J. CHOYKE AND C. E. NIELSEN, *Ohio State University.*—The diffusion cloud chamber is stable only when the density gradient is positive downward. This requirement sets a maximum of approximately −20°C for the top temperature of a diffusion chamber employing ethanol in helium, at atmospheric

pressure, and an even lower temperature if the partial pressure of helium is below atmospheric. We have designed a chamber employing liquid nitrogen refrigeration that operates at pressures of helium down to one-fifth atmosphere with a sensitive region 1–3 cm deep. This chamber is being employed in a magnetic field in the study of a β-ray spectrum too weak to be measured in the usual β-ray spectrometer.

H4. A Low Pressure Cloud Chamber Investigation of Range-Energy Relations. ROBERT G. MILLS, *University of California, Berkeley.*—An expansion cloud chamber has been developed which operates at a total pressure before the expansion of about 45 millimeters. Because the rate of evaporation of water is high and the temperature of the gas very low during the sensitive time, the density of the gas is actually higher after the expansion than before. When the chamber is operated with oxygen and water vapor, the stopping power of the gas during the sensitive time is 7.6 percent that of NTP air. When it is operated with helium and water vapor, the stopping power is 5.7 percent that of NTP air. The chamber has been applied to the problem of the low energy range-energy relations for protons, alpha-particles, and oxygen ions. Monoenergetic neutrons are produced by bombarding thin lithium films with protons from the Berkeley Van de Graaff generator. These neutrons pass through the cloud chamber, producing elastic recoils of nuclei present in the gas. The energy of a recoil is determined by measuring the angle between its direction and the direction of the neutron trajectory. The range-energy curves found are in essential agreement with previous work of other investigators.

H5. The Deterioration of Self-Quenching Counters. STEPHEN S. FRIEDLAND AND HENRY S. KATZENSTEIN, *University of Connecticut.*—To determine the effects of dissociation of the polyatomic vapor used in self-quenching counters, two counters connected together through a stopcock were prepared and one was run for 10^{10} counts till it no longer acted as a good counter. The deteriorated gas was pumped into the second counter and its characteristics obtained. The old shell was treated and the gas put back into it. A mass spectrometer was used to study the dissociation products of the gas, and the results so obtained are used to explain the nature of the operating characteristics of the counters.

H6. Temperature Effect on the Counting Rate of Boron Neutron Counters. AUREL GOODWIN, JR., AND MARIO IONA, *University of Denver.*—The counting rate of BF_3 neutron counters was found to be dependent on the temperature in experiments supported in part by the Research Corporation and by the Geophysical Research Division of the Air Force Cambridge Research Center. An analysis of this effect was undertaken by measurements of differential pulse-height distributions which were obtained by using an amplifier of variable calibrated gain and selecting pulses of a narrow size interval by means of a two-channel discriminator circuit. The differential pulse-height distribution shows a large number of small pulses due to the gamma-rays of the Ra-Be neutron source. In addition there are large pulses of varying size from the boron disintegrations due to neutrons. At room temperature the two parts are separated by a distinct minimum of almost zero. An increase in temperature will change the counting rate due to changes in neutron density and change in cross section of the boron neutron reaction. However, the counting rates are changed also by a shifting of the pulse-height distribution toward smaller pulses. The larger pulses being more affected than are the smaller ones.

H7. μ-Meson-Electron Scattering.* W. D. WALKER, *University of California, Berkeley.*—The spectrum of knock-on electrons produced by high energy μ-mesons is being measured. The experiment has extended the previous measurements[1] to higher electron energies. The primary particles are required to traverse 1200 g/cm² of lead in order to trigger the apparatus. The knock-on electrons are produced in a carbon plate placed in the middle of a cloud chamber which is in a magnetic field of 1500 gauss. Preliminary results agree with the calculated spectrum.

* Assisted by the joint program of the ONR and AEC.
[1] Walker, Hammel, Sinclair, and Sorrels, Phys. Rev. **83**, 655 (1951).

H8. Lifetimes of the μ^- Meson Stopped in Light Elements —Apparatus. W. E. BELL* AND E. P. HINCKS, *Chalk River Laboratories.*—Cosmic-ray μ-meson lifetimes are being determined with apparatus designed to record the time delays in the emission of decay electrons with good stability and high accuracy. Both meson and electron are detected in an arrangement, previously described,[1] of 3 counter trays *A*, *B*, and *C* under 5½-in. lead and 2-ft concrete. The meson absorber is placed in a 2-in. space between trays *B* and *C*. Discharges of *B or C* following, with a short delay, the coincident discharge of *A* and *B*, but not *C*, are observed, and the distribution of delays between 1 and 11 μsec is recorded with a 10-channel "interval analyzer." A calibration to determine the delay limits appropriate to each counting channel is made daily using a high precision double-pulse generator. Pairs of fast-rising pulses are derived from a continuous sine wave generated by an *RC* type oscillator, and are repeated at a suitable low rate. The oscillator frequency is continuously variable over a range 40:1, and is checked at several points against quartz crystals. The interval between the test pulses of a pair is determinable with an uncertainty <0.5 percent.

* Now with Newmont Exploration Ltd., Jerome, Arizona.
[1] W. E. Bell and E. P. Hincks, Phys. Rev. **84**, 1243 (1951).

H9. Lifetimes of the μ^- Meson Stopped in Light Elements —Results. E. P. HINCKS AND W. E. BELL,* *Chalk River Laboratories.*—Absorbers of Li, Be, and C were used in turn to stop μ-mesons, and with the apparatus described in the preceding abstract the distribution of delays for about 30,000 decay electrons was observed for each. After correcting for accidental events, and to standard channel gate widths, the decay curves appear to be single exponentials, the mean lifetimes (μsec) being for Li, 2.20 ± 0.02, for Be, 2.15 ± 0.02, and for C, 2.12 ± 0.03. Allowing for μ^+ mesons that decay in the absorber (the excess of μ^+ mesons of $\sim$500 Mev at sea level is taken as 20 percent) counter walls and supports with a mean life 2.22 ± 0.02 μsec,[1] the mean life (τ^-_{Li}), of slow μ^- mesons in Li is 2.15 ± 0.09 μsec—not significantly different from the μ^+ lifetime. Assuming that the lifetimes for *decay* of μ^+ and μ^- mesons are, in fact, equal, it follows that the *capture* rate (A_{Li}) by a Li nucleus of a μ^- meson in its *K* orbit is $<3.5\times10^4$ sec^{-1} (with 85 percent probability.) Similar analyses of the results for Be and C yield the following values: $\tau^-_{Be}=2.05\pm0.06$ μsec; $\tau^-_C=1.98\pm0.08$ μsec. The corresponding capture rates are $A_{Be}=(3.7\pm1.5)\times10^4$ sec^{-1}; $A_C=(5.5\pm2.1)\times10^4$ sec^{-1}.

* Now with Newmont Exploration Ltd., Jerome, Arizona.
[1] W. E. Bell and E. P. Hincks, Phys. Rev. **84**, 1243 (1951).

H10. Lifetimes of the π^- and π^+ Mesons.* H. LOAR, R. DURBIN, AND W. W. HAVENS, JR., *Columbia University.*—The lifetimes of the π^- and π^+ mesons have been measured under similar conditions. A 73-Mev meson beam of either sign is collimated and monitored by a 10-ft telescope of three thin stilbene counters, 1½-in. in diameter. An 8-in. diameter liquid scintillation counter is placed at a variable distance *L* behind the telescope. The number of fourfold coincidences per threefold monitor count is then measured as a function of *L*. The fourfold count rate decreases with increasing *L* due to the decay in flight of the π-mesons in the collimated beam. For decay at a distance greater than about 20 in. from the 8-in. counter, the μ-meson has a very small probability of being

counted. This probability is known from the kinematics of the reaction. The lifetimes were found to be $(2.55\pm0.19)\times10^{-8}$ sec for the π^- meson, and $(2.44\pm0.18)\pm10^{-8}$ sec for the π^+ meson.

* Sponsored by the joint program of the ONR and AEC.

H11. The Interaction Mean Free Path of π-Mesons in Lead.* FRITZ E. FROEHLICH AND KURT SITTE, *Syracuse University.*—An experiment is carried out at Echo Lake, Colorado (altitude 3260 m) to detect a possible difference between the interaction mean free paths of π-mesons and of nucleons. While the N-component incident from the atmosphere can be expected to contain in the energy region around 10 Bev, and at this altitude, only a few percent of π-mesons, this fraction would be considerably increased after "filtering" through a thick absorber if the mean free path of π-mesons exceeds that of protons. Consequently, one would then expect to observe a mean free path of the shower-producing radiation which increases with the absorber thickness, at least for absorbers of several times the proton mean free path. No such variation would be expected for less energetic showers since their primaries are practically all protons. The barometer effect offers a further check. Preliminary results of a run under 660 g/cm² show an increase in the interaction mean free path beyond the usual 165 g/cm², the reality of which will be discussed.

* Supported by the Air Force Cambridge Research Center.

H12. Multiple Scattering of Fast Pions in Photographic Emulsions. MEERA BACKUS AND J. J. LORD, *University of Chicago.*—The small angle multiple scattering of 218 ± 10 Mev negative pions in 200-micron thick Ilford G-5 emulsions has been measured by the sagita method. In order to test the theory at very long cell lengths, ninety pion tracks of average length about 9000 microns were measured at cell lengths of 250, 500, 750, 1000, and 2000 microns. The average scattering factor[1] for cells of 500 and 750 microns was found to be 25.2 ± 0.8 in an interval where spurious scattering corrections are negligible for these particles. This is in good agreement with the scattering factor obtained from monoenergetic protons from the Berkeley cyclotron.[2] The dependence of the average scattering angle upon the cell length is in fair agreement with theory. Comparison of these measurements with similar ones for cyclotron accelerated carbon nuclei of 1.1 Bev will be given.

[1] Martin Berger, sent for publication to *The Physical Review.*
[2] Berger, Lord, and Schein, Phys. Rev. **83**, 850 (1951).

H13. The Cosmic Radiation at Great Depths. WALTER GOAD, *Duke University and Los Alamos Scientific Laboratory.*—Greisen[1] has pointed out that the "knee" in the absorption curve of cosmic rays underground is probably due to the competition between nuclear collision and μ-decay of π-mesons after they have been produced. When one assumes that the mean free path for production of π-mesons by the primaries is equal the mean free path for interaction of π-mesons with nuclei, only two parameters enter this effect, the e-folding distance of the atmospheric density and the lifetime of the π-meson. With this assumption we have obtained from the underground data an energy spectrum with which π-mesons are produced in the range $10^{10}-10^{13}$ ev which is free of adjustable parameters. The effects of $\pi-\mu$ decay, and of all relevant electromagnetic processes have been included. The implications of these results for the properties of primary events involving multiple (or plural) production of mesons will be discussed.

[1] Kenneth I. Greisen, Phys. Rev. **73**, 521 (1948).

H14. Ionization Loss at Relativistic Velocities in Nuclear Emulsions. MAURICE M. SHAPIRO AND BERTRAM STILLER, *Naval Research Laboratory.*—Conflicting results have been reported on the variation of specific ionization I with velocity in nuclear emulsions (as measured by grain density g) at kinetic energies >2 rest masses. Interpretation of certain high energy phenomena requires a knowledge of this variation; yet the very existence of a rise in g above its minimum value g_{min} has been controversial. In 400μ Ilford G-5 emulsions exposed in the stratosphere we have measured g along the primary tracks of meson showers and along the shower tracks themselves. The frequency distribution in g of the shower tracks shows a peak at g_{min}, whereas the primaries of showers with multiplicity ≥5 show a well-resolved peak at about $g=1.10\ g_{min}$. This indicates that for energies >10 rest masses, I exceeds I_{min} by $\simeq10$ percent. High energy electron tracks provide corroborative evidence. These findings support those of Voyvodic[1] on the existence of a rise in ionization above I_{min} to a "plateau" at higher energies. Implications for the theory of ionization and for the identification of particles are discussed.

[1] L. Voyvodic, Conference on V-Particles and Heavy Mesons, Bristol, December, 1951.

TUESDAY MORNING AT 10:00

University of Denver

(E. TELLER presiding)

Radioactive Substances

I1. K/L Internal Conversion Ratio in $M4$ Transitions.* G. A. GRAVES, L. M. Langer, AND R. D. MOFFAT, *Indiana University.*—It is observed that the $K/L+M$ internal conversion ratios for $M4$ transitions fall somewhat lower than the empirical curve of Goldhaber and Sunyar[1] in the region of low values of Z^2/E. The observations were made with the large magnetic spectrometer with measured resolutions of from 0.5 to 1.1 percent, depending on source thickness. The following values were obtained for the energy of the transition and for the $K/L+M$ ratio: Y^{91}, 551.2 kev, 6.00; Sr^{87}, 388.2 kev, 5.79; Y^{87}, 381.3 kev, 5.41; Ba^{137}, 661.4 kev, 4.64; In^{113}, 391.7 kev, 4.21 and In^{115}, 334.6 kev, 3.76. These points fall on a curve which joins smoothly with the empirical curve at high values of Z^2/E.

* Assisted by a grant from the Frederick Gardner Cottrell Fund of the Research Corporation and by the joint program of ONR and AEC.
[1] M. Goldhaber and A. W. Sunyar, Phys. Rev. **83**, 906 (1951).

I2. The Tritium Beta-Spectrum and the Mass of the Neutrino.* L. M. LANGER AND R. D. MOFFAT, *Indiana University.*—A direct determination of the beta-momentum spectrum of H^3 has been made in the large magnetic spectrometer. The

source is a thin and uniform layer of tritiated succinic acid[1] thermally deposited in vacuo onto a 1.5-microgram/cm² Zapon backing. A G-M counter with a 1.5-microgram/cm² Zapon side window is used for detection. The spectrometer was operated with a resolution of 0.7 percent. The Fermi plot of the data obtained with the thickest source (about 1 mC) is straight from about 7 kev out to the end point. Preliminary measurements indicate that the rest mass of the neutrino is less than 0.1 percent the mass of the electron, if it is the anti-neutrino that accompanies negatron emission. On the basis of the *Th A* line at $H\rho = 533.66$,[2] the maximum energy of the H^3 spectrum, obtained with a grounded source, is 18.0 ± 0.4 kev. It is anticipated that more precise data will be available in time for the meeting.

* Assisted by a grant from the Frederick Gardner Cottrell Fund of the Research Corporation and by the joint program of ONR and AEC.
[1] We wish to acknowledge the cooperation of E. S. Robinson and J. G. Povelities of Los Alamos Scientific Laboratories in preparing the tritium sources.
[2] H. Craig, Phys. Rev. **85**, 688 (1952).

I3. Low Energy Portion of the S^{35} Beta-Spectrum. G. J. PLAIN, H. L. MORRISON AND F. T. ROGERS, JR., *Inyokern.*—The low energy portion of the S^{35} beta-spectrum has been observed after the general method of H. O. W. Richardson and Alice Leigh-Smith, using a radioactive vapor in a continuously sensitive diffusion cloud-chamber. The activity was carried on trace quantities of labeled ethyl mercaptan.* One thousand low energy beta-tracks were measured, out of approximately 25,000 tracks recorded on nonstereoscopic photographs. Only those tracks which were well defined and in focus over their entire length were selected. From the observed spectrum it appears that there are few, if any, beta-particles from S^{35} having energies below 10 kev.[1]

* Obtained under AEC authorization No. 11695.
[1] Cook, Langer, and Price, Phys. Rev. **74**, 548 (1948).

I4. The Beta Spectrum of As^{76}. E. P. TOMLINSON AND S. L. RIDGWAY, *Princeton University.*—The As^{76} spectrum was investigated for information bearing on the interpretation of angular correlation measurements (abstract JA2 of the 1952 Washington meeting). Using the high resolution Siegbahn type double-focusing spectrometer, data on the highest energy spectrum (end point 2.98 ± 0.01 Mev) gave a Kurie plot originally curved, rectified by the p^2+q^2 factor, indicating a transition of type $\Delta J = 2$, (yes). Subtraction gave for the next highest energy transition an end point at 2.40 ± 0.03 Mev. K conversion electrons were observed with energy corresponding to a transition of 558 ± 6 kev. Accepting Siegbahn's[1] decay scheme, the K conversion coefficient is $(2.0 \pm 0.2) \times 10^{-3}$ implying electric quadrupole according to Rose *et al.*[2] Assuming a zero even ground state of Se^{76} these date give two even for the first Se^{76} excited state and two odd for As^{76}. This work was supported in part by the AEC, and the Higgins Scientific Trust Fund.

[1] K. Siegbahn, Arkiv. Mat. Astron. Fysik, **34A**, No. 7 (1948).
[2] Rose, Goertzel, and Perry, ORNL Report 1023.

I5. Photoproduction of the Isomeric Pair of Bromine^{80}. ERICH M. HARTH, *U. S. Naval Research Laboratory.*—The relative yields of Br^{80} and Br^{80m} have been investigated by Fairhall,[1] using different nuclear reactions. It seemed desirable to obtain the ratio σ_g/σ_m of the number of nuclei produced in the ground state and the metastable state when they originate in a (γ, n) reaction. Bromine samples shielded with cadmium were irradiated with the bremsstrahlung spectrum from a 22-Mev betatron. The decay curves of the activities induced in the sample could be readily resolved by a subtraction method into the 4.4^h half-life of Br^{80m}, the 18^m half-life of Br^{80}, and a 6^m activity due to the $Br^{79}(\gamma, n)Br^{78}$ reaction. The ratio σ_g/σ_m was then obtained from the extrapolated initial 4.4^h and 18^m activities and the length of irradiation. Some of the ratios thus obtained are given in Table I as functions of the maximum photon energy. The values are in very good agreement with those obtained by Katz and others[2] using a similar method.

TABLE I.

E_{max}(Mev)	10.5	10.7	10.8	11.0	11.2	11.7	14.2	18.3	22.2
σ_g/σ_m	14	18	28	18	13	8.5	4.2	2.2	1.8

[1] A. W. Fairhall and C. D. Coryell, Bull. Am. Phys. Soc. **27**, No. 3, 39 (1952).
[2] Katz, Pease, and Moody, Bull. Am. Phys. Soc. **27**, No. 3, 20 (1952), and private communication to Dr. L. Seren.

I6. Radiations of Rh^{99} and Ga^{67}. S. C. FULTZ, R. J. NASH, R. L. WOODWARD, AND M. L. POOL, *Ohio State University.*—Radiations from Rh activities produced by bombardment of Ru metal with 6.3-Mev protons, were examined in a 180° focusing spectrometer. Internal conversion peaks corresponding to gamma-rays with energies of 0.144 ± 0.005 and 0.286 ± 0.005 Mev were observed and their half-lives measured. Both gamma-rays were found to decay with a long half-life of 4.3 days, corresponding to Rh^{101}, but the 0.286-Mev gamma-ray also decayed with a shorter half-life of 4.5 hours. Lack of positrons observed from Rh^{101} would indicate that the 0.286-Mev gamma-ray arises from Rh^{99} and is not an isomer of Rh^{101}. The gamma-rays of Ga^{67} have been examined by the coincidence method. The 295- and 180-kev gamma-rays have been confirmed as being in cascade, but the 90-kev gamma-ray is not in coincidence with the harder gamma-rays. Preliminary x-ray−gamma-ray delayed coincidence measurements made on a scintillation spectrometer indicate that the 90-kev gamma-ray is metastable, with a half-life in the microsecond range. Disintegration schemes for Ga^{67} and Rh^{99} will be presented.

I7. The Angular Correlation of the Gamma-Rays Emitted from the Excited States of Cd^{114}.* ROLF M. STEFFEN AND W. ZOBEL, *Purdue University.*—The angular correlation of the 548- and 715-kev gamma-rays of In^{114} has been measured using sources of $InCl_3$, $In_2(SO_4)_3$, and In metal sources. In spite of the short lifetime of the intermediate state ($< 2 \times 10^{-9}$ sec) an appreciable effect of the chemical state of the In^{114} sources on the angular correlation has been observed, the metal sources giving the supposedly unperturbed angular correlation: $f(\vartheta) = 1 + 0.09 \cos^2\vartheta + 0.07 \cos^4\vartheta (\pm 0.01)$. This correlation function is in good agreement with that reported before,[1,2] however the more accurate data make a revision of the former interpretation necessary. The observed angular correlation can be described in terms of a 4–2–0 cascade in which the 4–2 transition is a mixture of octupole and quadrupole radiation, or in terms of a 2–2–0 cascade in which the 2–2 transition is a mixture ($\delta = 0$) of quadrupole (4.4 percent) and dipole radiation (95.6 percent). In both cases the 2–0 transition to the ground state is by quadrupole radiation. The investigation of the 73-sec In^{114} ground state, produced directly by deuteron bombardment of In and Cd, showed conclusively that the gamma-cascade follows the K capture decay of the 72-sec In^{114} ground state indicating a spin 2 for the 1.26-Mev level of Cd^{114}.

* Work supported by the AEC.
[1] Rolf M. Steffen, Phys. Rev. **83**, 166 (1951).
[2] Johns, Cox, and McMullen, Bull. Am. Phys. Soc. **27**, No. 1 (1952).

I8. The Disintegration of Ce^{144} and Pr^{144}. FRED T. PORTER AND C. SHARP COOK, *Washington University.**—The radiations from the radioactive chain $Ce^{144} \rightarrow Pr^{144} \rightarrow Nd^{144}$ have been investigated, using chemically purified sources. Ce^{144} (295-day half-life) decays to the ground state of Pr^{144} through a 70 percent abundant beta-group having a maximum energy of 304 ± 2 kev. Conversion electrons have been observed which indicate

that within the praseodymium nucleus there are transitions having energies 33.7, 53.5, 80.7, 100.3, and 134.2 kev. The predominant number of the Pr^{141} beta-transitions go directly to the ground state of Nd^{141} through a 2.97 ± 0.01 Mev beta-group. Conversion electrons from a weak 60.3-kev transition in neodymium have been observed. Very weak gamma-radiation having energies 0.696, 1.5, and 2.185 Mev have been observed. The beta-spectrum indicates that less than 2 percent of the beta-transitions go to excited states of neodymium at 0.696 and 2.185 Mev. Using the evidence available a disintegration scheme will be proposed.

* Supported by the joint program of the ONR and AEC.

I9. Radioactivity of Pm^{142}, Pm^{143}, Pm^{145}, Pm^{146}, and Sm^{146}. JOHN K. LONG, M. L. POOL, AND D. N. KUNDU, *Ohio State University.*—7-Mev proton bombardments have been performed on enrichments of the isotopes of neodymium. An activity has been observed with a half-life of 250–280 days in Pm^{142}. The activity consists largely of electromagnetic radiation and is therefore believed to be K capture. In Pm^{143}, a K capture activity was observed with a half-life of 300–350 days. Pm^{145} has been found to have a positron activity of 0.45 ± 0.05 Mev with a half-life of 14–18 days. Pm^{146} decays by negative beta-particle emission of energy 0.75 ± 0.10 Mev with a half-life of $1\frac{1}{4}$–$2\frac{1}{4}$ years. Samples of neodymium bombarded with deuterons in years past now show a low intensity alpha-particle activity, which supports the expectation that Sm^{146} may decay to the magic number nucleus Nd^{142}. The alpha half-life is calculated to be 10^{4}–10^{6} years.

I10. Radioactivity of Osmium. J. B. SWAN AND R. D. HILL, *University of Illinois.**—Osmium activities of 15-day and 32-hour half-lives, which were previously ascribed to Os^{193} and Os^{191}, respectively, have now been positively assigned to Os^{191} and Os^{193}. Using ordinary osmium metal, both activities were shown to be present when samples were irradiated by pile neutrons, whereas the 32-hour activity was absent from samples activated by γ-rays from a 20-Mev betatron. A 14-hour activity, associated with a γ-transition of 74.2 kev, was also observed with both of the above irradiations. Conversion electron energies placed this activity in osmium. A growth of the 15-day activity, consistent with a parent half-life of 14 hours, showed that the 14-hour activity was in Os^{191}. The measured half-life of the 14-hour osmium activity probably identifies it as an $M4$ isomeric transition. It was confirmed that γ-rays of 41.7 and 129.1 kev follow the 15-day β-decay of Os^{191}. The 41.7-kev transition was identified as $E2$, and the 129.1-kev transition as an $M1$, $E2$ mixture. Long-lived γ-radiations of 650 and 228 kev have also been observed. These are probably associated with a previously reported 878 kev cross-over γ-transition in Os^{188}.

* Assisted by joint ONR and AEC programs.

I11. Radiations of Bi^{213}, Pb^{209}, and Tl^{209}. F. WAGNER, JR., M. S. FREEDMAN, D. W. ENGELKEMEIR, AND L. B. MAGNUSSON, *Argonne National Laboratory.*—The electron spectrum of the beta-active daughters in equilibrium with a sample of 10-day Ac^{225} was determined with a double lens spectrometer. The Kurie plot of the continuum was resolved into four components: 1.99 Mev, assigned to Tl^{209}; 1.39 and 0.96 Mev, assigned to Bi^{213}; and 0.62 Mev, assigned to Pb^{209}. Conversion electron lines were found at 417, 341, 200, 118, and 80 kev. A study of the equilibrium sample with a scintillation spectrometer showed gammas at 435, 230, and 165 kev and K x-rays. In a separated Bi^{213} sample gammas were found at 435 and at 120 kev. Coincidence measurements showed the 120-kev gamma to be in cascade with the 1.39-Mev beta. A study of the Pb^{209} beta-spectrum on a separated sample with the use of an anthracene scintillation spectrometer gave a Kurie plot with an end point of 640 kev. The 230- and 165-kev gammas are assigned to the alpha-activities present.

TUESDAY MORNING AT 10:00

Shirley-Savoy

(R. J. SEEGER presiding)

Invited Papers

J1. Recent Advances in the Theory of Magnetization. R. M. BOZORTH, *Bell Telephone Laboratories.* (45 min.)

J2. Noise in Electron Beams at Microwave Frequencies. D. A. WATKINS, *Hughes Research and Development Laboratories.* (45 min.)

TUESDAY AFTERNOON AT 1:45

Cosmopolitan

(W. B. PIETENPOL presiding)

Cosmic Rays

K1. Mass Determinations of Fast Cosmic-Ray Particles in Emulsions. L. VOYVODIC, *National Research Council of Canada.*—The mass spectrum of fast particles recorded in Ilford G5 emulsions is being investigated by means of the grain density-multiple scattering method, with particular emphasis on long tracks and precision measurements in order to obtain high mass resolution. Preliminary results are reported on shower particles and isolated tracks in 600-micron emulsions flown at high altitude. Besides pi-mesons and protons, two particles of intermediate mass have been found so far, with apparent masses of $1210\pm180m_e$ and $1330\pm200m_e$. The former event resembles the charged V-particle tracks occasionally observed

in cloud chambers, showing a change in direction through 20° with no visible recoil. The detailed analysis of this event is discussed.

K2. Collision Cross Sections in Cosmic-Ray Interactions. KURT SITTE, *Syracuse University.*—For heavy materials, counter experiments yield collision cross sections that are geometrical for very energetic primaries, and decrease with decreasing energy. Light nuclei are found to be "transparent" also at high primary energies. On the other hand, observations in cloud chambers and nuclear emulsions show large collision cross sections even for shower secondaries. Recently obtained data* are used to show that this discrepancy cannot be explained in terms of differences in primary energies, but is due to the inefficiency of counter experiments in eliminating preceding interactions. If due corrections are made, it appears that the counter data for heavy materials are compatible with a geometrical collision cross section for all primary energies above $\sim$0.75 Bev. An upper limit of (0.25 ± 0.15) can be deduced for the probability of charge exchange in collisions of cosmic-ray protons and neutrons. While present data do not permit a quantitative analysis of counter experiments with light materials, it can be concluded that the "transparency" effect has been overestimated, and that the cross sections are at least closer to the geometrical value than the usual estimate.

* Harth, Froehlich, and Sitte, Bull. Am. Phys. Soc. **27**, No. 1, 15 (1952).

K3. Collisions of Heavy Primary Nuclei in Emulsions. N. L. ALLEN* AND E. PICKUP, *National Research Council, Canada.*—A survey will be given of the different types of collisions of incoming primary nuclei with target nuclei in Ilford G5 emulsions exposed at about 85,000 feet. Some collisions appear to be with hydrogen nuclei. A few events will be described in detail, together with an interpretation of the disintegration and the nature of the products.

* National Research Council of Canada Fellow.

K4. A High Energy Nuclear Interaction.* J. E. NAUGLE, *University of Minnesota.*—A very energetic nuclear disintegration due to a primary nucleus with a charge of 7 ± 1 has been observed in an emulsion pellicle. 127 ± 5 tracks with a grain density at or near minimum originated at or within 0.25 radiation lengths of the point of disintegration. All but three of the particles were contained in a cone of half-width 3°. The existence of only 3 slow evaporation particles indicates that the primary collided with a light nucleus of the emulsion or made a grazing collision with Ag or Br. By following the shower through 3 cm of glass, it was possible to δ-ray and grain count on the fragment of the incident heavy. The charge of the heavy after the collision was (5 ± 1). If one assumes that the charged mesons are emitted symmetrically in the backward and forward directions with relativistic velocities in the center of mass system, then one can calculate the energy of the incoming primary from the shape of the angular distribution in the laboratory system. This method gives an energy of 1.4×10^{14} ev/nucleon for the incident particle and is obviously independent of the theory of meson production assumed. The angular distribution and multiplicity is consistent with that predicted by Fermi[1] if 4 or 5 nucleons of the incident nucleus suffered collisions with nucleons of the target nucleus.

* This work supported by the joint program of the AEC and the ONR.
[1] E. Fermi, Phys. Rev. **81**, 683 (1951).

K5. Narrow Angle Pairs from Nuclear Disintegrations. J. J. LORD, D. M. HASKIN, AND MARCEL SCHEIN, *University of Chicago.*—An investigation is in progress to study the nature of very narrow angle pairs of particles emitted from nuclear interactions in Ilford emulsions. Out of 160 meson-produced stars, one produced by a cyclotron accelerated 135-Mev negative pion consisted of a 17-Mev proton track and a pair of 0.005 ± 0.001 radian angular divergence. Each track is of minimum ionization within a statistical precision of 15 percent. From multiple scattering measurements the first of these particles must be less massive than about $\frac{1}{4}$ that of a muon while the upper limit of the mass of the other is approximately that of a muon. The pair is emitted at an angle of 110° with the direction of travel of the incident pion. If the particles are assumed to be electrons, then the total energy $(205\pm36$ Mev), the opening angles, and the angle of emission are not incompatible with the process that the incident negative pion is converted in an interaction with a proton of the nucleus to produce a 60-Mev neutron and a 230-Mev gamma-ray which in turn is internally converted to a pair of electrons in the Coulomb field of this nucleus. On the basis of our previous knowledge the probability of this process should, however, be extremely low. Other similar narrow angle pairs from cosmic-ray induced stars will be discussed.

K6. Interactions of Secondary Particles from Penetrating Showers.* N. M. DULLER, W. D. WALKER,† AND J. D. SORRELS,‡ *Rice Institute.*—The mean free path for penetrating shower production has been measured for secondary particles from showers in carbon and heavier elements. For charged secondaries from carbon showers the mean free path is found to be 400 ± 100 g/cm^2 in carbon and 750 ± 200 g/cm^2 in lead. The mean free path of secondary particles from showers starting in lead, iron or brass is 1000 ± 200 g/cm^2 in carbon and 900 ± 200 g/cm^2 in lead. The preliminary results seem to indicate that a sizeable fraction of the secondary particles from carbon penetrating showers have a cross section close to the geometric. Secondary particles from iron or lead have a smaller cross section for the production of penetrating showers, probably because they have, on the average, lower energy than secondaries from carbon. There are four times as many secondary penetrating showers produced by charged secondaries as by neutral secondaries.

* Supported in part by a grant from the Research Corporation.
† Now on leave at the University of California, Berkeley, California.
‡ Now at California Institute of Technology, Pasadena, California.

K7. Nuclear Transparency and Nucleon Cross Section for Penetrating-Shower Producing Cosmic Radiation.* DAROL FROMAN, *Los Alamos Scientific Laboratory.*—Assuming incident particles react independently with individual nucleons with effective cross section, $\sigma_0=\alpha\pi k^2$, and using $\sigma_n=\pi k^2A^{\frac{1}{3}}$ for the nuclear cross section, the effective collision length becomes $L_s=A^{\frac{1}{3}}/N\pi k^2[1-\exp(-\alpha A^{\frac{1}{3}})]$. Using $\alpha=0.44$ and $k=1.45\times10^{-13}$ cm, L_s agrees better than the "geometric" collision length, $L_g=A^{\frac{1}{3}}/N\pi(\hbar/\mu c)^2$, especially for light materials, with published measurements of collision lengths in CH_2, H_2O, C, air, Al, Fe, Au, and Pb for both charged and neutral incident particles. These values give a mfp for incident particles in nuclear matter of $\lambda=4k/3\alpha=4.4\times10^{-13}$ cm. Cocconi[1] uses $\lambda\approx4\hbar/\mu c=5.5\times10^{-13}$ cm to fit his observed and calculated collision lengths in Pb, Fe, and C. Fernbach, Serber, and Taylor[2] find $\lambda=4.5\times10^{-13}$ cm for 90-Mev neutrons. Choosing $\sigma_0=\alpha\pi k^2=29$ mb would lead to lower multiplicities of meson production in nucleon-nucleon interactions than Fermi's[3] estimates based on $\sigma_0=\pi(\hbar/\mu c)^2=60$ mb.

* Work performed under the auspices of the AEC.
[1] G. Cocconi, Phys. Rev. **75**, 1074 (1949).
[2] Fernbach, Serber, and Taylor, Phys. Rev. **75**, 1352 (1949).
[3] E. Fermi, Prog. Theoret. Phys. **5**, 570 (1950); Phys. Rev. **81**, 683 (1951).

K8. Close Pairs of Tracks in Showers in Emulsions. J. Y. MEI* AND E. PICKUP, *National Research Council, Canada.*—In an analysis of the showers of minimum ionization particles associated with energetic cosmic-ray stars there appear to be more close pairs of particles ($\gtrsim4°$ separation) than would be expected on a statistical basis, taking into account the average angular distribution for the shower particles. We have made measurements[1] for showers with n particles, where $6<n\gtrsim20$,

and it is hoped to give results for a more extended analysis. Possible interpretations for this effect will be discussed, including the recent suggestion of an intermediate, short-lived neutral meson.[3] Some of the particles have been identified as pions.

* National Research Council of Canada Fellow.
[1] J. Y. Mei and E. Pickup, Phys. Rev. (to be published).
[2] Danysz, Lock, and Yekutieli, Nature **169**, 364 (1952).

K9. Angular Distribution of Penetrating Secondary Particles from Showers in Carbon and Lead.* W. D. WALKER,† N. M. DULLER, AND J. D. SORRELS,‡ *Rice Institute.*—A comparison has been made between the angular distribution of penetrating secondary particles of showers originating in carbon and in lead. The angular distributions are very similar with the following exceptions. Showers from carbon have relatively more particles within a narrow cone in the direction of the primary particle. Showers from lead have relatively more particles projected at angles of 40° or more from the direction of the primary particle. Several cases have been found showing pairs of penetrating secondary particles separated by angles of the order of 3° or 4°. Sometimes these pairs are found at wide angles, with respect to the direction of the primary. Similar events have been described by Danysz *et al.*[1] as the decay of a particle with low Q and very short lifetime. More pairs of particles appear to come from showers in carbon than in lead.

* Supported in part by a grant from the Research Corporation.
† Now on leave at the University of California, Berkeley, California.
‡ Now at the California Institute of Technology, Pasadena, California.
[1] Danysz, Lock, and Yekutieli, Nature **169**, 364 (1952).

K10. On the Lateral Structure of Electronic Showers in Air. M. H. KALOS AND J. M. BLATT, *University of Illinois.*—The distribution of particles at any depth and energy as a function of distance from the shower axis can be shown to satisfy an integro-differential equation which does not involve the angular distribution of the particles.[1] A similar equation will be presented for the angular distribution at any depth and energy (integrated over the lateral distance). A variation-iteration technique which converges to the solution can be formulated. A result for the tracklength value of the angular distribution is obtained by inserting a plausible trial function into the diffusion equation. Iteration of this result provides an estimate of its validity. A general explicit formula has been derived for the $2n$th moment of the tracklength value of the lateral distance in approximation A ($\beta \ll E \ll E_0$). The first 8 moments (up to and including r^{16}) have been computed using the ORDVAC electronic digital computer. These moments disagree with the ones derived from Molière's[2] function for monoenergetic electrons. The true distribution appears to have more of a "tail." Further work toward the solution of the corresponding diffusion equation will be reported.

[1] Echo Lake Cosmic Ray Symposium, paper no. 66 (June, 1949).
[2] G. Moliere, in W. Heisenberg's *Cosmic Radiation* (New York, 1946), Chapter 3.

K11. Effects of the Atmosphere on the Penetrating Cosmic Radiation. H. O. CURTIS AND E. S. COTTON, *Air Force Cambridge Research Center.*—Data obtained with a cosmic-ray telescope operated continuously from October 9 to November 22, 1950, has been analyzed to determine more completely than previously[1] the effects of the atmosphere on the radiation observed. For each day in the period the average height for the production of the mu-mesons was computed by weighting the heights of various pressure levels according to the probable distribution of originating levels obtained by Sands.[2] The average density of the air confronting the pi-mesons was computed for each day by weighting the actual densities at increasing pressure levels exponentially to account for the absorption of the pi-mesons. The mean hourly counting rate, the station pressure, and the two parameters above were analyzed for statistical correlation. The results of this analysis will be presented.

[1] E. S. Cotton and H. O. Curtis, Phys. Rev. **84**, 840 (1951).
[2] M. Sands, Phys. Rev. **77**, 180 (1950).

K12. Burst Production in Material of Low Atomic Number by Cosmic Rays at Sea Level.* F. E. DRIGGERS,† *University of Michigan* (*introduced by* W. E. Hazen).—A large ionization chamber has been used to obtain an integral burst size-frequency distribution by amplifying and recording the electron pulses produced. A comparison of the integrated burst rate from the upper hemisphere with that produced by primaries with a small zenith angle permitted an estimate of the burst rate resulting from interactions of the N component. Calculations were made of the expected burst distributions arising from the electromagnetic interactions (bremsstrahlung, knock-on, and direct pair production) of spin 0 and spin $\frac{1}{2}$ μ-mesons. About $\frac{1}{3}$ of the observed bursts were attributed to the N component. The remaining burst rate agreed with the rate calculated for spin $\frac{1}{2}$ mesons to within the estimated uncertainty of the calculations—about 15 percent. Only if it is postulated that at least $\frac{1}{2}$ of the bursts generally attributed to μ-mesons arise from specifically nuclear force interactions are these results consistent with a spin of 0 for the μ-meson. If this possibility could be eliminated, these data would indicate a spin of $\frac{1}{2}$.

* Supported in part by the joint program of the AEC and ONR and by an AEC fellowship.
† Now with E. I. du Pont de Nemours & Company, Argonne National Laboratory.

K13. New Barometric and Temperature Coefficients for Small Cosmic-Ray Bursts. JAMES W. BROXON, *University of Colorado.*—Measurements and statistical procedures have been described.[1] Records for three months of the 1947–8–9 series were read by a fifth reader with improved conditions. For two of these, considerably better correlation was indicated. Previously noted disagreement among the readers, however, was augmented. Partial barometric and temperature coefficients were determined for the 1-mm bursts of the 1938–9 series, for each of the 18 months. These, also, were predominately negative. Comparison of monthly coefficients for the two series indicates that there was no considerable dependence of the coefficients upon the magnitudes of the different 1-mm bursts. In spite of the much smaller number of bursts, having only two readers appears to have provided vastly superior statistical reliability for coefficients based upon the entire period of the 1938–9 series. The best value for the barometric coefficient is about -4.6 percent/mm Hg and for the temperature coefficient, -2.5 percent/°C, based on daily average values. Using monthly averages, -9.1 percent/mm and -2.2 percent/°C are obtained. The latter are less reliable, but have significance ratios above the 1 percent level. Earlier positive long-time temperature coefficients are believed to have been caused by differences among readers.

[1] J. W. Broxon, Phys. Rev. **81**, 555 (1951).

TUESDAY AFTERNOON AT 2:15

University of Denver

(W. M. ELSASSER presiding)

Optical Physics

L1. A Survey of Isotope Shift in OI.* LEE W. PARKER AND JOHN R. HOLMES, *University of Southern California.*—An O^{18}-enriched oxygen sample (donated by A. O. Nier) has allowed examination of isotope structure in 18 atomic lines between 2000 and 10,000A. Strong sharp lines were obtained in a liquid nitrogen-cooled electrodeless quartz discharge tube containing about 0.2 mm of oxygen and 2 mm of helium excited by a 10-mc oscillator. The discharge was photographed through an external Fabry-Perot interferometer in series with a large prism spectrograph. The shifts were found to range from zero to as high as 0.5 cm^{-1} for λ2884. A semi-quantitative check on the mass effect theory is furnished by shifts in lines connecting states of the $2p^33p$ configuration through intermediate states of opposite parity. The specific mass effect should be the same for all states arising from the $2p^33p$ configuration, assuming Russell-Saunders coupling.[1] Thus the observed relative shifts between pairs of such states should be given by the normal mass effect alone. This is found to be true in two out of three cases, within experimental accuracy. Some newly resolved fine structure will be reported later.

* Supported by the ONR.
[1] See J. H. Bartlett, Jr., and J. J. Gibbons, Jr., Phys. Rev. **44**, 538 (1933), whose treatment of the $2p^33p$ configuration in Ne can be applied to $2p^33p$ in oxygen.

L2. Infrared Rotational Spectrum of Hydrogen Sulfide.* E. E. BELL, R. L. HANSLER,† AND R. A. OETJEN, *The Ohio State University.*—The infrared rotational spectrum of H_2S from 65 cm^{-1} to 250 cm^{-1} has been obtained and correlated with the energy levels predicted by Crawford and Cross.[1] The goodness of this correlation will be discussed.

* These measurements were obtained with a far infrared spectrograph constructed under contract between Wright Air Development Center and the Ohio State University Research Foundation.
† Eastman Kodak Research Fellow.
[1] B. L. Crawford and P. C. Cross, J. Chem. Phys. **5**, 621 (1937).

L3. Microwave Absorption and Dielectric Relaxation in Some Long-Chain Esters.* P. L. MCGEER, A. J. CURTIS, G. B. RATHMANN, AND C. P. SMYTH, *Princeton University.*—Dielectric constants and losses between 3° and 90° have been measured at wavelengths of 1.25, 3.22, and 10.0 cm and 577 m for thirteen long-chain esters. The critical wavelength, at which the loss is a maximum, increases with molecular length and with viscosity, as observed previously for alkyl bromides. The viscosities of the esters are slightly lower than those of alkyl bromides of approximately the same molecular length, but the critical wavelengths are only about half as large. This shows a greater ease of orientation of the esters, which may be due, in part at least, to the fact that the orienting dipole in the esters does not occur at the end of the molecular chain. Orientation of polar molecular segments, presumably, occurs by rotation around carbon-carbon bonds, which gives rise to a distribution of relaxation times. The distribution increases with increasing size of the ester molecule and decreases with increasing temperature.

* Supported in part by the ONR.

L4. The Spectral Distribution of Energy in the Fluorescence of Sodium Fluorescein. EARL H. GILMORE, *Inyokern.*—In most instances the experimentally observed emission band of sodium fluorescein is altered considerably by self-absorption. A study has been made to determine photometrically the character of the unaltered band. The emissions from solutions of differing concentrations were studied spectrally with a combination photomultiplier-tube monochromator. Integrated forms of Beer's law equations were used to arrive at the final results. The final curve obtained closely resembles that obtained by Nichols and Merritt[1] by visual photometry. Their observations were made on a line perpendicular to the exiting beam, whereas in the present work the observations were from the front and from the rear of the cell and on a line 45 degrees from the exiting beam.

[1] E. L. Nichols and E. Merritt, Phys. Rev. **30**, 328 (1910).

L5. Instantaneous Measurement of Transient Flame Temperatures.* GEORGE W. BAUSERMAN, *University of Denver* (*introduced by* Robert S. Bradford).—An instrument has been developed to determine the time-temperature relationships of sub-explosive flames of short duration. This instrument is based on a modification of the line-reversal method of temperature measurement. Descriptions will be given of the line-reversal method and of the modification of this method upon which the instrument is based. The design of the optical system and the electronic components of the instrument will be described, along with the method of producing test flames for use with the instrument. The method of calibration and determination of the accuracy of the measurements, and typical results obtained with the instrument, will also be discussed.

* This research is supported by the Ordnance Department of the United States Army.

L6. Wavelength Independent Photographic Dosimeter Employing Terphenyl Intensifying Screens.* HERMAN HOERLIN AND FRANK KASZUBA, *Ansco Research Laboratories.*—The emission of several organic scintillators has been investigated under gamma and x-ray excitation in the $\lambda_{eff}=0.01$ to 0.60A range. Their fluorescent efficiency decreases rapidly with increasing wavelength. This trend is in marked contrast with the response of photographic film to the same radiation which is known to be low for the shorter and high for the longer wavelengths. The characteristics of intensifying screens and of film can therefore be matched to yield a dosimeter having fully wavelength independent response in the indicated range. Mechanically rigid and highly efficient screens containing 145 mg/cm^2 terphenyl powder, 105 mg/cm^2 Lucite and 4 mg/cm^2 $PbCl_2$[1] were made by a simple molding technique. Screens are placed in contact with both sides of a special, double coated monitoring film designed for medium light sensitivity and for very low reciprocity law failure in the 1-second to 40-hour exposure range. This dosimeter permits the monitoring of gamma- and x-ray dosages of 0.02 to 10 roentgens with a maximum interpretation error of 25 percent.

* Work supported by subcontract with the Argonne National Laboratory.
[1] Addition of $PbCl_2$ recommended by J. E. Rose and L. D. Marinelli, Chicago.

L7. Contrast and Color in Interference Fringes. H. W. WEDAA AND E. W. PRICE, *Inyokern.*—In applications using the Mach-Zehnder interferometer, the use of an approximately monochromatic light results in a loss of identity of the zero-order fringe so that the fringes all appear alike. This is a

serious disadvantage since a particular fringe can no longer be traced across discontinuities in the picture nor can it be identified in sequences of pictures. In recent work using a magnesium spark and a 4481A interference filter, it has been found that the zero-order fringe can be identified either by eye or with a photometer provided the interferometer is adjusted so that the color disperion in each branch of the interferometer is exactly the same. The dispersive effect of an excess of 2×10^{-4} inches of glass in one branch of the interferometer is illustrated by the lack of symmetry of color dispersion about the order zero in white light fringes using color films and the lack of contrast in fringes using a filtered spark. The excess glass is produced by rotating one of the interferometer plates on its horizontal axis through a small angle.

L8. Multiple-Beam Interferometric Study of Topaz Cleavage Faces and Polished Glass Surfaces. W. F. KOEHLER, *Inyokern.*—Multiple-beam fringes of equal chromatic order were formed by the film between the surface being investigated and an appropriately silvered optical flat. Crystal cleavage steps were determined from measurements of fringe steps. The *c*-dimension of the unit cell of topaz was determined by a method of successive approximations to be 8.77 ± 0.04A which agrees with the x-ray value within the experimental error. The local smoothness of polished glass surfaces in the range of several angstrom units, was measured using these techniques. The contours of the surfaces studied thus far do not indicate flow of glass during polishing, which is contrary to the Beilby Flow Theory.

Post-Deadline Papers, if Any

TUESDAY AFTERNOON AT 2:15

Shirley-Savoy

(K. K. DARROW presiding)

Invited Papers

M1. The Perception of Speech by Deafened Listeners and Its Relation to the Design of Hearing Aids. HARVEY FLETCHER, *Brigham Young University.* (30 min.)

M2. Shock-Wave Phenomena. R. J. SEEGER, *National Science Foundation.* (30 min.)

TUESDAY EVENING AT 7:00

University of Denver

(E. FERMI presiding)

Banquet of the American Physical Society

WEDNESDAY MORNING AT 9:30

Cosmopolitan

(E. FERMI presiding)

Session P

Discussion on the Components of the Cosmic Radiation

Discussion Leader: E. FERMI.

Members of the Panel: K. GREISEN, W. E. HAZEN, H. V. NEHER, E. P. NEY, E. TELLER, M. S. VALLARTA, J. A. WHEELER, and others to be chosen by the Discussion Leader.

WEDNESDAY AFTERNOON AT 2:00

Shirley-Savoy (Empire Room)

(A. C. GRAVES presiding)

Invited Papers

Q1. Measurements of Neutron-Spectra Using Nuclear-Emulsion Techniques. LOUIS ROSEN, *Los Alamos Scientific Laboratory.* (30 min.)

Q2. The Los Alamos Fast Reactor and Its Experimental Use. D. B. HALL, *Los Alamos Scientific Laboratory.* (30 min.)

Q3. Precision Measurement of the Annihilation Radiation and Decay Schemes of Tantalum 182 and Iridium 192. H. C. HOYT, *California Institute of Technology.* (30 min.)

WEDNESDAY AFTERNOON AT 2:00

Cosmopolitan

(J. A. VAN ALLEN presiding)

Symposium on Temperature, Composition and Motions of the Upper Atmosphere

R1. The Distribution of Atmospheric Ozone between 25- and 65-km Altitude. J. A. VAN ALLEN, *Iowa State University.* (25 min.)

R2. Study of Upper Atmospheric Winds by the Echo Methods. L. A. MANNING, *Stanford University.* (25 min.)

R3. Lunar Tides in the Ionosphere. A. G. MCNISH, *National Bureau of Standards.* (25 min.)

R4. Atmospheric Temperatures and Pressures at High Altitudes. H. NEWELL, JR., *Naval Research Laboratory.* (25 min.)

R5. Gravitational Separation in the Upper Atmosphere. L. M. JONES, *University of Michigan.* (25 min.)

THURSDAY MORNING AT 9:30

Shirley-Savoy

(J. KAPLAN presiding)

Session S

Discussion on Composition, Winds, Pressures, and Temperatures of the Upper Atmosphere

Discussion Leader: J. KAPLAN.

Members of the Panel: R. A. CRAIG, C. T. ELVEY, H. E. NEWELL, JR., MARCUS O'DAY, R. PENNDORF, and others to be chosen by the Discussion Leader.

THURSDAY AFTERNOON AT 2:00

Shirley-Savoy

(E. ROSSI presiding)

Session T

Discussion on the New Unstable Particles in Cosmic Radiation

Discussion Leader: B. ROSSI.

Members of the Panel: C. D. ANDERSON, E. FERMI, W. B. FRETTER, R. B. LEIGHTON, R. E. MARSHAK, C. PEYROU, M. SCHEIN, R. W. THOMPSON, H. YUKAWA, and others to be chosen by the Discussion Leader.

SUPPLEMENTARY PROGRAMME

SP1. The Use of a Radioactive Vapor in a Continuously Operating Diffusion Cloud Chamber.* G. J. PLAIN AND H. L. MORRISON, *Inyokern.*—A mixture of radioactive S^{35}† in the compound ethyl mercaptan and ethyl alcohol has been used in a diffusion type cloud chamber. Because of condensation of vapor on the bottom, extreme care must be exercised to prevent overloading. An activity of 8 mc in a volume of 1.18 cc of ethyl mercaptan had to be diluted with ethyl alcohol to one part in 10^8. It was observed during operation that a potential difference is developed between the top and bottom plates of the chamber. This potential difference influences the formation of the beta-tracks. Measurements indicated that if the bottom was one volt negative with respect to the top the quality of the tracks was noticeably reduced. When the bottom was made two volts negative track formation ceased. The best tracks were obtained when the top and bottom plates were maintained at the same potential.

* Obtained under AEC authorization.
† To be given at the end of Session H if the Chairman rules that time permits.

SP2. Experimental Demonstration of Kinks. GEORGE ANTONOFF.*—The discovery of kinks appears to be in contradiction with the classical view, which assumes the properties *vs* temperature change continually. For this reason the experimental results are distrusted by most people, inclined to attribute them to the experimental errors. This effect is purely psychological. The liquid must be brought into equilibrium by keeping it in a thermostat for some time. The thermo-control within 0.1°C is quite sufficient. Weighing of a pycnometer of 25 ml on an analytical balance will show the kinks quite distinctly and unquestionably. The effect is perfectly reproducible if the above conditions are followed. My theory, now forty years old, predicted the kinks and has shown itself in perfect agreement with the experimental evidence [see J. chim. phys. (Paris), Feb. (1952)].

* To be given at the end of Session C if the Chairman rules that time permits.

The First Denver Meeting of the American Physical Society

Every one of the first ten meetings of the American Physical Society was held in New York City; but when the Society at last decided to quit the confines of Manhattan, it bounded all the way to Denver. No Bulletin was issued for that eleventh meeting; and the omission of fifty-one years ago is now repaired by printing here in toto *the Minutes thereof. It is a pleasure to record that one of the authors of papers presented at that meeting—Professor Gordon Ferrie Hull—is still a Fellow of the Society. The paper given at this meeting was the first disclosure of the Nichols-Hull observations of the pressure of light.*

A joint meeting of the American Physical Society and Section B of the American Association for the Advancement of Science was held in the High School Building at Denver, Colorado, Thursday morning, August 29th, 1901.

In the absence of the President and Vice-President, Edward L. Nichols was made Chairman, *pro tempore.*

Benjamin W. Snow was elected Secretary, *pro tempore.*

The following papers were presented:

1. **Note on the Supposed Elongation of a Dielectric in an Electrostatic Field.** L. T. MORE.
2. **On Electro-Striction.** J. S. SHEARER (read by E. L. NICHOLS).
3. **The Pressure of Heat and Light Radiation.** E. F. NICHOLS and G. F. HULL (read by B. W. SNOW).
4. **The Heat of Combustion of Acetylene.** H. A. RANDS (read by title).
5. **The Fall of Temperature Through a Wedge-Shaped Wall of Glass.** ARTHUR BALL (read by title).
6. **On a New Method of Determining the Curve of Luminosity by Homogeneous Comparison.** D. B. BRACE.

BENJAMIN W. SNOW
Secretary, *pro tempore*

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The American Physical Society

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(To be sent to Professor Byron E. Cohn, University of Denver, Denver, Colorado)

I EXPECT to attend the dinner of the American Physical Society at seven o'clock on Tuesday evening, July 1. My party will comprise ..... persons.

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